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MAKING FARM DECISIONS IN A RISKY WORLD: A GUIDEBOOK

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PREFACE

This guidebook provides a comprehensive overview of the principles and techniques for making risky decisions. Risky decisions involve choosing between alternatives, some or all of which have results that are not certain. Most, if not all, decisions made by agricultural managers (farmers and ranchers) involve risk; and for the major decisions, these risk considerations are crucial. The importance of these risk considerations has not yet been adequately reflected in the educational programs for present and potential agricultural managers.

Written to the agricultural manager, this guidebook also serves as a basic reference for use by extension educators in agricultural economics and by undergraduate instructors of farm management and agricultural marketing. The material presented has been distilled from an extensive review of current literature. The material selected is that which, based on our experience with farmers and students, we believe will be most useful in a farm management context.

This guidebook should be viewed as a working document. We are still in the initial stages of developing and testing educational programs to help agricultural managers deal with risk in making decisions. In the next few years we will develop new approaches and learn from our successes and failures. Thus, the draft should be viewed as a presentation of what we currently know and understand. It is not the final answer. This guidebook will evolve over time as our understanding of the decision-making process improves; we develop more fully our techniques of decision analysis; and new educational methods are tested and proven.

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Chapter 1

INTRODUCTION

Managing a modern farm operation in today's complex and risky world is no easy task. You face uncertainty as you plan for the future. Ever-changing conditions in your decision environment provide important challenges for you, the farm manager.

This risk and uncertainty in agriculture is not a new phenomenon. Farmers have been taking risks for years:

> You take risk that it will rain at the right time.
> You take risk when you buy a used tractor.
> You take risk that you won't lose your farm lease.
> You take risk that prices won't increase after you sell.
> You take risk that government regulations won't change.
> You take risk that your new combine won't become obsolete.
> You take risk that your employee won't quit.

When we say that the farmer makes decisions under risk and uncertainty, we're simply saying that you don't know what's going to happen in the future. For any particular decision there are a number of possible results depending on many factors which are beyond your control. While there is no way of knowing what the exact result will be, many times you have some information about the likelihood of different results. The level of knowledge, however, varies considerably from complete uncertainty to fairly reliable predictions.

The purpose of this guidebook is to suggest an approach to decision-making using techniques that allow you to deal deliberately and reasonably with this risk and uncertainty. These specific management techniques will be the topics of later chapters.

Two important points about risky decision making should be discussed. First, a good risky decision does not guarantee a good outcome. A good decision simply means it is consistent with the decision maker's information about the risks involved and with his objectives. Thus, a good decision is a carefully considered choice based on all the available information. Whether the decision turns out to be right or wrong, after the fact, is partly a matter of luck. Second, the approach to risky decision making presented here serves to aid the decision maker through the analysis of his decision problems. The techniques do not replace the decision maker, and as we will see, his knowledge and objectives are an integral part of the techniques we will be discussing.

In this chapter we will want to take care of some preliminary questions such as the following:

- What do risk and uncertainty mean?
- What are the sources of risk?
- Why is uncertainty a problem?

After a discussion of each of these questions, we will turn to the critical one, "how can you deal with the risk involved in making farm decisions?"

SOME DEFINITIONS

To avoid misinterpretation and provide a common base for beginning this discussion of risk and uncertainty, we offer some definitions.

The term "uncertainty" used in this guidebook refers simply to a situation in which a number of different outcomes, irrespective of their desirability, are recognized as possible. Thus, uncertainty refers to a situation in which the future cannot be predicted with certainty. The decision maker may have knowledge or beliefs about the chances of occurance for these outcomes. Or, with no information regarding which will occur, he assigns each outcome equal odds. In this case, he is completely uncertain. The acquisition of information would reduce his uncertainty.

We propose taking as a definition of "risk", its more common usage in a decision-making context. Here it refers to the chance of adverse outcomes associated with an action. All other things equal, the greater the uncertainty, the greater will be the risk associated with a particular decision situation.

With explicit recognition of the decision-maker's knowledge and beliefs regarding the future, the distinction between risk and uncertainty is weaker. The terms are often used interchangeably in this guidebook.

SOURCES OF RISK IN AGRICULTURE

Risk is not a new phenomenon to agricultural managers. Farmers have always taken risks. Identifying the different sources of risk is an important part of the decision-making process. The relative importance of these major sources of agricultural risk differ among enterprises and change over time.

1. Production and Yield Risk. This source of risk is due to the variability in yields and production caused by such unpredictable factors as weather, disease, pests, genetic variations, and timing of practices. Examples include variations in crop yields, animal weaning weights, product quality, animal rate of gain, pasture carrying capacity, feed conversion, death loss, labor required, machinery breakdown, etc.

2. Market and Price Risk. This refers to the variability and unpredictability of prices which farmers receive for products and pay for production inputs. Types of variation in prices which are relatively predictable are trends, commodity cycles, and seasonal variation. In addition, random price variations result from changing supply and demand conditions including such influences as buyer and seller expectations, speculation, government programs, and consumer demand.

3. Business and Financial Risk. This source of risk relates to the financing of the business, the assets it controls, and its credit obligations. This type of risk has become more important with the larger capital investments required in agriculture today as well as the increased use of borrowed capital. Variable cash flows increase the risk of not having adequate cash to meet debt payments and other financial obligations. Another example of this source of risk is the possibility of losing the lease on the land being farmed.

4. Technology and Obsolescence Risk. The rapid development of new technology can make current production methods obsolete shortly after important investments have been made. Adopting new technologies too soon or too late is a risk farmers must face. For example, when planning to purchase a new tractor, a farmer should consider the risk that technological advances could result in a more efficient tractor which will make the one purchased obsolete within a short time.

5. Casualty Loss Risk. This is a traditional source of risk referring to the loss of assets to fire, wind, hail, flood, and theft. Although it's not a new source of risk, inflation has greatly increased the value of potential losses.

6. Social and Legal Risk. Governmental laws and regulations are a major source of uncertainty for farmers. Examples include environmental protection, controls on the use of feed additives, insecticides, and herbicides; and land use planning. These stem from changing social attitudes. In addition there is also the risk of law suits from liabilities due to such things as farm accidents and missuse of chemicals.

7. Human Risk. The character, health, and behavior of individuals are unpredictable and contribute to the risk in farm management. The possibility of losing a key employee during a critical production period is one example of this risk. Dishonesty and undependability of business associates are others. The disabling of the farm manager can be very disruptive to the continuity of an efficient farm operation. Also, family needs and goals change, sometimes unpredictably.

Psychological studies have shown that many business managers, farmers included, tend to ignore some important sources of risk that are associated with their business operation. This is a natural tendency, but previous good luck does not guarantee future success. Ignoring uncertain variables oversimplifies the decision problem. We should recognize all the sources of risk and deal with them in our management decisions, so as to make better decisions consistent with our objectives.

EFFECTS OF UNCERTAINTY

Why is uncertainty a problem? Uncertainty causes inefficiency in the economic system and individual frustration. Some examples illustrate the point.

Because of increased uncertainty, the farmer may not apply as much fertilizer as he would if he knew what the crop price would be. As a result yield per acre is reduced. Because of uncertainty, the farmer may not buy the additional 80 acres which would allow his machinery and labor to be used more efficiently. Uncertainty affects not only the quantities of resources used, but also the mix of products produced.

Because of uncertainty, it is more difficult for the farmer to borrow capital to make efficiency-increasing investments. If lenders view farm loans as more risky, they will likely (1) reduce the amount of funds extended, (2) increase interest rates, (3) increase security requirements, (4) decrease the term of the loan, and/or (5) increase the supervision of the loan.

The increasing size and commercialization of farms has amplified the impact of uncertainty. A larger proportion of inputs are purchased from off-farm sources, and specialization has decreased the diversity of farm enterprises. Larger farms use more debt capital, and the problems of financial management are aggravated by variable cash flows.

There are also social consequences of uncertainty. As uncertainty increases in agriculture, it becomes more difficult for the farmer to determine the course of behavior which will be consistent with his particular goals. This leads to individual frustration which, in turn, affects personal interactions. Individuals may develop behavioral characteristics such as aggression, regression, and withdrawal. These barriers to interpersonal relations not only have consequences for families in rural communities, but also for the coordination of the food and fiber production and distribution system. If a communication breakdown develops between the farmer and his lender, or his supplier, a lack of coordination and a reduction in efficiency can result.

DEALING WITH RISK IN MAKING DECISIONS

Uncertainty has important management implications for the individual farmer. If you are to react deliberately and reasonably, there are three steps you should consider as an approach to making these risky decisions:

1. You should analyze your decisions in terms of alternative actions, possible events, and payoffs.
2. You should estimate the odds (probabilities) associated with the events affecting the payoffs to your decisions.
3. You should consider your attitude about taking risks, including your ability and objectives for doing so.

The techniques for implementing this approach to farm decision making are the subjects to be treated in subsequent chapters. Chapter 2 provides an overview of the principles of decision making under uncertainty. In chapter 3 guidelines and procedures for preparing the payoff matrix are outlined.

The estimation and use of subjective probabilities are discussed in chapter 4. Alternative probability estimation techniques are presented, and the computation of the different forms of management information from probabilities is explained. Chapter 5 illustrates how the decision maker's attitudes about risk taking are formed and how they influence decision choice.

The management approach presented in this guidebook is a logical procedure for making risky decisions. It brings together all the pertinent aspects of the decision. Most importantly, if fully recognizes the personal element in decision making: (1) the knowledge and beliefs of the manager and (2) his objectives and attitudes about risk-taking.

The steps outlined above amount to no more than explicitly spelling out the thought processes you already use intuitively in making risky decisions. However, many decisions are too complex and important to be handled by intuition. This more formalized approach helps assure that your risky choices are in line with your objectives and that all the information available to you has been fully utilized.

Chapter 2

DECISION - MAKING PRINCIPLES

Our framework for risky decision making is based on the idea that the decision maker can choose among alternative actions, the outcomes of which depend on something we call "events". These events are not under the control of the decision maker and their occurrence is uncertain. The outcome of each action for each event is termed a payoff and a table showing the actions, events, and payoffs is called a "payoff matrix". This chapter introduces the payoff matrix and discusses how various decision rules can be applied to the information in the payoff matrix to select actions. Some of these rules incorporate subjective probabilities and the decision-maker's attitudes about risk taking.

THE PAYOFF MATRIX

Consider the case of a wheat grower who is in the midst of harvesting his wheat crop. His wheat crop will be about 10,000 bushels which he can sell at harvest time for $3.50 per bushel. He has plenty of on-farm storage and usually has stored wheat for sale in the spring. Seasonal wheat price movements in the past few years have been such that frequently it has not been profitable to store the crop. In fact, some years the price has actually fallen, rather than risen from harvest time to spring.

To simplify the problem, let's assume that our wheat grower has two possible actions: (1) sell at harvest and (2) sell in April. Also, suppose that there are only three possible events:

1. The price will increase $0.60 (to $4.10) by April,
2. The price in April will be equal to the harvest time price of $3.50, and
3. the price will decrease $0.30 per bu. (to $3.20) by April.

The wheat grower has done some thinking about the cost of storing the crop and has decided that the variable cost of putting his wheat in storage and taking it out again is about 5 cents per bushel. Interest on the money invested in the wheat will be about 2.5 cents per month for 8 months, or a total of 20 cents. Total variable cost of storing the wheat is about 25 cents per bushel.

The information relevant to this problem can be displayed in a payoff matrix as shown below:

	Actions	
Events	A_1 Sell at harvest ($)	A_2 Sell in April ($)
E_1 - price up 60¢	35,000	38,500
E_2 - price stable	35,000	32,500
E_3 - price down 30¢	35,000	29,500

If our grower sells at harvest (Action A_1) he will receive $35,000 for his crop, regardless of what happens to the wheat price between harvest and next April. If he sells in April (Action A_2), his storage cost will be $2,500. If the wheat price is stable, his sales net of storage cost will be $32,500. If the price increases 60 cents per bushel his net sales income will be $38,500. If the price decreases 30 cents, his net sales will be $29,500. Thus the payoff matrix summarizes the problem. It shows the payoff from each alternative for each of the possible events.

How would this payoff matrix help our example farmer in making his decisions? Let's look at some alternative decision rules.

RULES FOR MAKING RISKY DECISIONS

Many decision rules have been proposed for use in risky or uncertain situations. Some of these will be described and illustrated, using the wheat sale example. The payoff matrix for the example summarizes the decision problem, but does not indicate which action should be taken. If the wheat grower knew which event would occur, he could easily select the best action for that event. However, at this point let's assume he doesn't have any knowledge about which event will occur. We will look at a couple of techniques proposed to help solve this decision problem of which action to choose when the decision maker has no knowledge about which event may occur. Later we'll look at some decision rules for situations in which the decision maker has some knowledge of the probabilities of occurrence of the various events.

Maximin Rule

This rule would be used by a risk averter, someone who prefers to avoid risk. The objective is to obtain the best of the worst outcomes. To use this criterion, the decision-maker first selects the worst outcome for each action. Then he selects the best of these worst outcomes and chooses the action that goes with it. This is a pessimistic approach in that attention is focused on the events with the worst outcomes.

In our wheat sale example, the worst the grower could do by selling at harvest is $35,000. The worst he could do by selling in April is $29,500. Using the maximin criterion, he would choose A_1 and sell at harvest.

Using the maximin criterion, the decision maker is assured of receiving no less than the return indicated. If he chooses another alternative, he might achieve a higher return, but he might also achieve a lower return. Thus, maximin is a conservative or pessimistic decision criterion.

Maximax Rule

This decision-making rule would be used by the risk taker, the gambler who prefers risk. Using this criterion, the decision maker chooses the highest value in the payoff table. Rather than looking at the minimum payoff for the action, he looks for the maximum of each and then selects that action which gives the largest of these maximums.

The example wheat grower would be comparing $35,000, the highest payoff if he sells at harvest with $38,500, the highest payoff if he sells in April. He would select A_2 and sell in April. The maximax rule focuses on the possibility of achieving the best possible outcome and ignores the possibility of an event with a poor outcome. It is consistent with the attitude of the "gambler" or risk taker.

These two decision rules, maximin and maximax, assume that the decision maker has no knowledge about which event will occur. While this may be true in some situations, many times you will have at least some information about the chances, or probabilities, of the occurrence of the various events. For example, in our wheat sale case, the decision-maker may know (or believe) that the chances of either a stable or increasing wheat price are greater than the chance of a decreasing wheat price.

Expected Monetary Value Rule

The use of the decision rule of maximizing expected monetary value (EMV) assumes that the decision-maker has some knowledge about the likelihood of the occurrence of the various events. To illustrate the use of expected monetary value, we'll use a portion of the wheat sale problem. Our wheat grower has decided that there is no chance of a price decline between harvest and April. In statistical terms, that's equivalent to saying that the probability of a price decline is zero. We are left with two events, (1) a 60 cent price increase and (2) a stable price between harvest and April. Let's think about the sale decision in terms of these two events.

Suppose that E_1 and E_2 are equally likely, that is, each has a probability of 0.5. That's the same as saying that each has a 50 percent chance of occurring. Such would be the case if over a long period of years, half the time we could expect the wheat price to remain stable and half the time to increase 60 cents between harvest and April.

If our example grower was playing the long-run odds, similar to flipping a coin where he would expect half heads and half tails, he could calculate the expected average income from each action and select the action that would give the largest average payoff in the long run. In this situation, the average payoff for A_1 (sell at harvest) is $35,000 and for A_2 (sell in April) it is $35,500. In this simple case, the expected value is calculated by multiplying each payoff times its probability and summing the result as shown below for A_2:

$38,500	x	0.5	=	$19,250
32,500	x	0.5	=	16,250
Expected monetary value			=	$35,500

We will call this result "expected monetary value" (or EMV).

Let's approach this problem from a different viewpoint. The example grower has studied seasonal price changes over the past 25 years and found with the exception of a few years, wheat prices have increased from harvest to April. He found that in many of those years prices increased more than enough to pay variable storage costs. He also recognizes that with high dependence on exports, wheat prices are not likely to be as stable now compared to earlier years. Therefore he believes that the probability of a harvest to April price increase is greater than 0.5 but it is not 1.0. More specifically, he believes that the probability of a 60 cent price is 0.6 and the probability of a stable price is 0.4. Therefore, the EMV of holding wheat until April (A_2) is:

$38,500	x	0.6	=	$23,100
32,500	x	0.4	=	13,000
Expected monetary value			=	$36,100

The EMV of $36,100 for holding is greater than the EMV of selling, which remains at $35,000. Therefore, our grower should sell in April if he wants to maximize EMV.

At this point a few comments about subjective probabilities will be helpful.

<u>Subjective Probability: A Brief Introduction</u>

You have probably recognized that the probabilities we have been using relative to the wheat selling decision are not the same as the probabilities related to flipping a coin. Most people would agree that if a coin is flipped a large number of times (say 100 or 1,000) that half the time we would get heads and half the time tails. Therefore, the probability of heads is 0.5 and tails, 0.5. We can call these "objective" probabilities. They do not depend on opinions. The coin toss can be repeated many times and the probabilities can be demonstrated.

The wheat price example is quite different. While we can study seasonal wheat price movements over a long period of time (say 100 years) we cannot establish objective probabilities of particular kinds of seasonal price movements that would allow us to bet on the future of wheat prices in the same way we might bet on a coin toss. Also, many wheat growers cannot "play the game" of holding or selling wheat over and over like a gambler can on a coin toss game. If probabilities of particular seasonal wheat price movements were developed, they would likely reflect the biases of the analyst who developed them. We call probabilities that are influenced by the person who developed them "subjective", or "personal", probabilities.

<u>Risk Attitudes: Another Brief Introduction</u>

When we use the terms "attitude toward risk" or "aversion to risk" we are talking about how the attitudes of a decision maker influence his actions when he faces uncertain situations. Perhaps the "risk neutral" situation is a good starting point. A risk neutral person can be described as one who acts as if he is maximizing "expected monetary value". In an uncertain situation, he will choose the action that would maximize EMV. Hence we call him an "EMV'er". In our wheat selling example with an 0.5 probability of a 60 cent price rise, a risk neutral decision maker (or EMV'er) would choose A_2 (sell in April) because it has the highest EMV.

A "risk averter", however, might not choose A_2, depending on his degree of aversion to risk. Our problem can be structured in a way which more clearly will illustrate the risk associated with holding the wheat for sale in April.

If the wheat is held, the grower has equal chances of gaining $3,500 or losing $2,500 compared to selling at harvest.

	Probability	Sell in April
Price increases 60¢	0.5	$ 3,500
Stable price	0.5	-2,500

Any decision maker who would prefer selling the wheat at harvest rather than holding it for sale in April is a risk averter. But we don't know how much of a risk averter. To help you think about how much of a risk averter you are, let's play a gambling game.

Suppose that I offer you the chance to win or lose $2,500 on the toss of a coin. You may call either heads or tails. If you call correctly, you will win $2,500; if not, you must pay me $2,500. So that neither of us reneges, we'll each give $2,500 to a neutral party who will then pay the winner. Would you take this gamble? If you would, you are "risk neutral" for amounts of money around $2500. The EMV of this gamble is zero.

Win $2,500 x 0.5 =	$ 1,250
Lose 2,500 x 0.5 =	-1,250
EMV =	$ 0

If you could play the game many times you would expect to have net winnings of zero which is exactly where you would be if you didn't play the game at all.

If you would not take the gamble you are a risk averter. There's nothing bad about being a risk averter. In fact, one of our purposes is to help you decide how much of a risk averter you are. This should help you make decisions which are consistent with your personal degree of risk aversion. That doesn't mean that all of your decisions will be the best you could have made after the fact. No one can guarantee such decision making. We can only help you make decisions consistent with the information you have and your degree of aversion to risk.

"Safety First" Rule

The "safety first" or minimum income criterion is closely related to the rule of maximizing expected monetary value. With the safety-first criterion, the decision maker has multiple objectives stated as:

(1) Maximize expected value of net income, subject to

(2) an acceptable probability of exceeding a minimum level of net income.

For example, decision maker's objectives could be to maximize expected net income subject to a $5,000 minimum net income that must be exceeded with a 0.9 or 90 percent probability. Any action that has less than a 90 percent chance of yielding a net income below $5,000 would not be accepted. Another decision maker might have a minimum income objective of $10,000 that must be exceeded with an 85 percent probability.

Using this decision rule means that the farmer orders his preferences. The first priority is to be able to achieve a minimum level of income with an acceptable probability (safety first). The second priority, once the first has been satisfied, is to maximize expected net income (EMV).

The minimum income level usually would be related to the decision maker's cash needs to cover cash costs, debt payments, and family living expenses. In a farm situation with more than one enterprise, the availability of cash from other enterprises usually would affect the minimum income and probability level associated with it. In some cases, the decision maker would need to consider the interaction of his possible payoffs from this decision with the payoffs from other decisions.

The safety-first rule will be illustrated with the wheat sale example used earlier. This grower's only enterprise is wheat and he has no other source of income. The payoff matrix is converted to net cash incomes. His cash costs (variable costs plus fixed cash costs and debt payments) are $25,000. In addition, he needs $9,000 for family living expenses. In total then, his minimum payoff required to meet his commitments is $34,000. A cash income below this level would represent a disaster.

Events	Subjective probabilities	Actions A_1 Sell at harvest	A_2 Sell in April
E_1, price up 60¢	0.6	\$35,000	\$38,500
E_2, price stable	0.4	35,000	32,500
Expected monetary value		\$35,000	\$36,100

He will not accept an action with more than a 20 percent chance of falling below a \$34,000 payoff. Referring to the payoff matrix above and using the safety-first criterion, he would choose A_1 and sell at harvest even though A_2 has a larger EMV. Selling in April has a 40 percent chance of producing a \$32,500 payoff and therefore does not meet his multiple objectives.

The safety-first decision rule can also be illustrated with slightly more complicated example. Suppose a farmer must decide whether to fertilize lightly, moderately, or heavily. The payoff matrix is:

Events	Probability	Actions A_1 Fertilize lightly	A_2 Fertilize moderately	A_3 Fertilize heavily
		--Net return (\$) from 400 acres --		
E_1 - low rainfall	0.2	8,000	5,500	2,000
E_2 - average rainfall	0.3	10,000	12,000	11,000
E_3 - high rainfall	0.5	11,000	15,000	18,000
Expected Monetary Value		10,100	12,200	12,700

The long range forecast is for high rainfall and our decision maker partly believes the forecaster. Therefore, our decision maker's subjective probability for E_1 is 0.2; E_2, 0.3 and E_3, 0.5. The EMV's using these subjective probabilities are as shown.

Our decision maker's minimum income objective is \$5,000 and he will reject any action with 20 percent or more chance of producing a net income below \$5,000. Action A_3 has the largest EMV (\$12,700) but has a 20 percent chance of falling below \$5,000. Therefore, he would choose A_2, because it has the highest EMV and less than 20 percent chance of producing an income below \$5,000.

The decision maker's safety-first objectives depends on his attitude about risk taking. This attitude will determine his "disaster" level of income and the probability he is willing to accept of having income below this minimum.

What if, in his attempt to apply the safety-first rule, the decision-maker cannot find a feasible alternative consistent with his objectives. Suppose in the previous fertilization example the minimum income objective was $9,000 which must be achieved at least 20 percent of the time. None of the three alternative actions satisfy this objective. Our example manager must either quit farming or redefine his objectives. Rather than using the safety-first rule, he might employ a trial and error process in arriving at his best decision choice. Instead of setting the minimum level of income and probability of not falling below this minimum, the decision maker would feel his way towards the "best" action without explicitly defining his objectives. Looking at each of the decision alternatives, he would compare them individually to see which brings him closest to attaining his objectives. The decision maker uses the payoff matrix to consider the probabilities of obtaining various levels of income for each decision alternative.

SUMMARY AND CONCLUSIONS

This chapter, through the use of illustrations, has presented an overview of decision-making under uncertainty. The payoff matrix simply summarizes the possible payoffs for the decision alternatives and the various events that can occur influencing the payoffs. It gives the decision maker the range of the possible consequences for each alternative action, but the payoff matrix cannot, itself, indicate the best decision. It simply summarizes information to be considered. Various decision rules can be applied to the information in the payoff matrix to determine the best decision.

Two somewhat naive rules are the maximin and maximax rules. The maximin rule would be used by the decision maker who prefers to avoid risk, while the maximax rule would be used by the risk taker. Both of these rules suffer from the deficiency that they do not consider the information that the decision maker may have available regarding the chance of occurrence for the various events affecting the decision payoffs.

If the decision maker has information regarding the chance that various events will occur, that is, he has subjective probabilities, and further if he is risk neutral, that is, he has no preference either to avoid or to take risk, then an appropriate rule for decision making under uncertainty is to maximize the expected monetary value of the payoffs. The payoffs from the matrix are combined with the subjective probabilities to compute the expected values and then the decision maker selects that action which has the highest expected monetary value.

In the case where the decision maker seeks to avoid risk, that is, he is a risk averter, the safety-first rule can be applied. In this case the decision maker has two objectives to mazimize and satisfy. As with the previous rule the decision maker maximizes expected monetary value, but this objective is secondary to achieving a minimum payoff with some acceptable probability. The decision maker's attitudes about risk will determine what the level of minimum income is and what is an acceptable probability for achieving this minimum. This decision rule has a great deal of flexibility and can be applied in a large number of situations. It considers the decision maker's degree of risk aversion. However, it is not applicable for those decision makers who are risk takers.

At this point you may be confused by the number of possible decision rules and the fact that we have not told you which one to use. Unfortunately, there is no one rule which is best. The choice depends on the information available and your attitude toward risk.

The safety-first criterion is consistent with the thinking of many decision makers who are risk averters to some degree. Each decision maker, of course, will have his own level of minimum income and acceptable probability. We have also found that in some cases the minimum income objective and probability can only be formulated after the decision maker has prepared the payoff matrix and seen the payoffs and probabilities.

It is this process of decision-making under risk that is the focus of this guidebook. The specification of the uncertain events, budgeting of payoffs, estimating your subjective probabilities, and considering your attitudes about risk taking force you to think in more detail about the risky consequences of your decisions. The components of this process of decision making, i.e., the payoff matrix, subjective probabilities, and risk attitudes, are the topics of the remaining chapters.

Chapter 3

THE PAYOFF MATRIX

There are no easy decisions when it comes to planning for the future where the only choices are between risky alternatives. In addition to different degrees of uncertainty, these alternatives may also require different efforts and involve different costs. The first and critical step then in planning in this environment is to realize that alternatives are available to you and what they imply in terms of the range of possible results.

This chapter outlines some guidelines and procedures for constructing the payoff matrix. The payoff matrix is simply a convenient format for summarizing the components of the decision problem. Let's use a simple example to illustrate.

Suppose you are faced with three alternatives involving the toss of a fair coin. Heads you win, tails you lose. The first alternative would be to bet $100, the second $10,000, and the third would be to decline both bets (Table 3-1). These alternative actions are the first component of the decision problem. The second component is the events which determine the outcomes for each of the actions. In this case the possible events are "heads" or "tails". The third component is the payoff or outcome associated with each action/event combination. In the case of the "don't bet" action, the payoffs are zero for each of the two events. For the "small bet" alternative, the payoffs are plus $100 and minus $100, depending on the event, and for the "large bet" alternative, the payoffs are plus $10,000 and minus $10,000.

Table 3-1. Payoff Matrix for Coin-Toss Decision Problem.

Events	Alternative Actions		
	Don't bet	Small bet	Large bet
	($)	($)	($)
Head	0	100	10,000
Tail	0	-100	-10,000

The decision problem consisting of its three components can be simply represented in a table form called the payoff matrix. Such a table summarizes the payoffs for all possible action/event combinations. Thus all the essential information for the coin-toss problem is shown in Table 3-1 which has columns corresponding to actions and rows corresponding to events.

STEPS TO CONSTRUCT THE MATRIX

The construction of the payoff matrix for any particular decision problem implies the following three steps:

1. List the alternative actions that are relevant. (Usually these are listed across the top of the table.)
2. List the possible events (or combinations of events) which could occur, influencing the payoffs of any of the possible actions. (Usually events are listed down the left of the table.)
3. Budget out the payoff (usually a monetary gain or loss) for each action/event combination and enter these payoffs in the appropriate spaces in the table.

It is important to recognize, however, that the simplicity of the payoff matrix in Table 3-1 is deceptive. Several types of events may affect the payoffs. For example, in a real life farm management decision, both prices and yields may be subject to uncertainty and the combined effect of the price event and the yield event will determine the payoff. Also many more than three alternative actions may be possible. Finally, the payoffs may require very complex budgeting procedures for estimation.

In carrying out these steps for many decision problems, it will be impractical to assess all possible actions and events. There are just too many for practical consideration.

Examples of Actions:

1. To buy or not to buy additional land.
2. To use alternative levels of fertilizers.
3. To sell wheat at harvest or hold for later sale.
4. To graze stockers on wheat pasture.
5. To buy or not to buy crop insurance.
6. To buy one of several alternative sizes of tractors.
7. To grow how much of each crop.

Examples of possible events:

1. The long term average wheat price may be $2.50, $3.00, $3.50, or $4.00.
2. Rainfall may be abundant, moderate, or scarce.
3. Grain exports may be low, average, or high, etc.
4. There may be hail or no hail.
5. Labor may be abundant or scarce.
6. The weather may be dry in winter and wet in summer, dry in winter and summer, relatively wet in winter and dry in summer, etc.
7. Cattle may gain .75 lb/day, 1.25 lb/day, 1.75 lb/day, etc.

The key is to limit the decision problem to the most promising actions and the most significant events affecting the payoffs of these actions. Some practice and skill, therefore, is needed to keep the matrix as simple as possible without losing the essentials of the decision problem.

This chapter deals with procedures and guidelines for determining events, specifying alternative actions, and budgeting the payoffs for the action/event combinations. In subsequent chapters we will discuss how probabilities can be estimated for the occurrence of each of the events and how attitudes about risk taking can be considered to determine your best decision choice.

Selecting the Most Promising Alternative Actions

For a given decision problem there is usually a wide range of alternative actions that would be possible. Take the decision problem of whether to purchase a new tractor. At first glance this might appear to be a simple yes or no decision. However, after more careful study, we might see that the decision is not just whether to purchase a tractor but also what tractor to purchase and perhaps whether to purchase it this year or next. What size, make, model, color? These are all alternative actions. Also, will the tractor be purchased outright or will the farmer borrow to make the purchase? If so, from whom will the money be borrowed and under what terms? There are also some decision alternatives associated with not purchasing or keeping the old tractor. Should the farmer give it a complete overhaul or simply fix it up enough to keep it running another year? Thus, you can see that we have expanded our rather simple yes-no decision problem into a very complex list of alternative actions to be considered.

Now, if our farmer had lots of time to study and budget each of these alternatives, or if he had access to a large computer, it would be possible to consider all of these alternatives in making these decisions. However, this is usually not the case. Therefore, we are suggesting the following guidelines for narrowing the list of alternatives to be considered.

After thinking about all of the possible alternatives, you should eliminate those that are clearly unattractive or not feasible, leaving only a few for inclusion in the payoff matrix. Following are four questions to keep in mind as you select the most promising alternatives.

1. Does the alternative action relate to the solution of the management problem? If the business has a heavy debt load, alternatives that call for additional borrowing would not be relevant.

2. Will the alternative action contribute to the objectives of the decision-maker? It is not realistic to assume that you will implement an alternative that does not fit your preferences. It may require labor that you do not want to perform or risks that you are not willing to take.

3. Is the alternative action consistent with the resources available? Is there enough labor available to implement the decision? Does

the alternative require equity capital that is not available?

4. Is the alternative action within the realities of the farmer's present management capabilities to implement? Because of the wide differences in management skills and abilities among farmers, the range of feasible alternatives varies considerable from farmer to farmer.

Determining the Significant Events

There are few decision alternatives in agriculture that are not subject to uncertainty with regards to the payoff. The wide variety of phenomena will influence the payoffs, for example, prices received, rainfall, temperature, whether the employee gets the work done on time, prices paid for inputs, etc. It is not possible to consider all of these eventualities in the construction of the payoff matrix; however, it is important to specify those that will be the most significant in determining the payoffs of the various decision alternatives. Past experience and a thorough knowledge of the biological, physical and economic processes involved will help in determining which events will be most critical.

Farmers, and businessmen in general, would rather not think about all of the "bad" events that can occur. However, it is important in the process of constructing the payoff matrix to think about the bad events as well as the good ones. A natural inclination is to ignore some of the uncertainties with which it is difficult to deal. Thus, it is important to discipline yourself to think through these uncertainties, learn more about their origins, and thus develop a better understanding of how they can affect the payoffs from your decisions.

Two factors are important in determining which events are significant or critical in affecting the payoffs of the alternative actions. These are (1) the possible impact or total magnitude of the effect that the event can have on the payoff and (2) the chance that this extreme event will occur. Obviously, if there is no chance that the event will occur based on the information available, then it can be ignored in constructing the payoff matrix. However, it is a matter of judgement regarding whether an event with a small but significant chance of occurring should be included. This judgement needs to be made considering the possible impact that this event might have.

This means that you may need to do some preliminary budgeting to estimate the size of the possible impact. An event with a small chance of occurrence but a large impact might be worthy of consideration, while one with a small impact compared to other events could well be ignored.

The events as they are combined in the payoff matrix must be organized in a particular way. For a logical analysis, the events must be combined so as to be mutually exclusive and collectively exhaustive. Mutually exclusive means that only one of a group of events can occur. That is, if one event in the payoff matrix occurs, none of the other events in the matrix can occur. Collectively exhaustive means that the events listed in the payoff matrix include all the possible outcomes. For example, if next year's wheat price could be anywhere between $2.00 and $4.00, this entire range of prices should be included as possible events. For convenience, this would usually be done in 10¢ and 25¢ intervals but it is important that the entire range of prices that are likely to occur be included in the payoff matrix.

Budgeting the Monetary Payoffs

Once the decision has been specified in terms of the alternative actions and possible events, the next step is to budget the payoffs for each action/event combination. Budgeting can be a complex and frustrating process involving an investment of the decision maker's time. However, this budgeting in the framework of a payoff matrix, preparing not just one budget, but preparing budgets for each action and event combination. Things may not go as the farmer had hoped or planned. However, with careful budgeting of all of the possible payoffs in the matrix, he should not be surprised at the actual outcome. He will have considered this eventuality before he made the decision.

Usually the payoffs are measured in monetary terms, although this is not necessary. For example, the decision maker may wish to maximize some other objective such as leisure time or physical production. The payoffs do not need to be expressed in dollar value but may represent other measures consistent with your objectives such as leisure time, etc. Furthermore, it's quite appropriate to put more than one measure in each cell of the payoff matrix. Assuming that the manager has multiple objectives, he might want to include two or more measures of the payoffs.

An important concept to keep in mind when computing the payoffs is the separation of the relevant cost and return items from the irrelevant ones. Relevant costs are those that are affected by the action or alternative under consideration, and conversely, irrelevant costs are those not affected by the alternative under consideration. Recall that in the wheat sale example in the previous chapter, we included in the cost of holding wheat for April sale only those costs that would be incurred as a result of choosing this alternative. The fixed costs of the grower's existing storage, such as depreciation, taxes, and interest will not differ whether or not he stores wheat this year and therefore are irrelevant. On the other hand, when the farmer holds the wheat until April rather than selling it at harvest, he foregoes the return on the money invested in the wheat. This money could be used to repay debts or it could be invested elsewhere. The opportunity cost of the money invested in the wheat is a relevant cost to wheat storage and therefore should be included in the calculation of the payoff from holding the wheat.

SOME BUDGETING CONCEPTS

This section details some specific concepts relative to the construction of the payoff matrix. There are two basic types of budgets prepared for determining the payoffs for the action/event combinations.

The Total Farm Budget

This budget includes all of the costs and receipts for the farm business. Several measures of financial performance or profit might be used and are discussed in a later section. This type of budget would be used in a situation where the alternate actions affect the use of all or most of the farm resources, such as would be involved in a major reorganization of the farm. Examples of decisions involving the use of the total farm budget would be changing the mix of farm enterprises or increasing the size of the farm.

The total farm budget involves the preparation of a complete income statement and the supplementary statements required for its completion. Such supplementary statements might include livestock inventory and feed requirements, land use and crop production, and machinery inventory and depreciation, and labor use and cost. Several references are available which detail the procedures and provide forms for completion of a total farm budget. Some are listed at the end of this chapter.

The Partial Budget

The partial budget, on the other hand, includes only those costs and returns which are actually affected by the alternative actions. It is simpler to prepare and eliminate the time needed in arriving at and listing those costs and income items which will not be affected by the decision. You only list the affected items, not the whole farm income and expense statement. Adding a small beef cow herd, for example, will only involve extra cattle costs and returns, so to test its profitability the farmer does not need to include all of the crop costs and returns which will remain unchanged. The result of the partial budget is to show the payoff in terms of the net return above relevant (or variable) costs.

Most decisions for an on-going farm business involve only parts of the business, that is, only certain income and expense items will be affected if a particular alternative action is taken. Examples of decisions that could utilize partial budgets are (1) adding a new enterprise without changing existing enterprises, (2) buying a machine rather than custom hiring, (3) the application of a chemical insecticide or herbicide, and (4) deciding when to sell grain.

Proposed changes ar alternative actions for an on-going farm business can take three basic forms based on their affects:

1. Input-Output. This type of change involves increasing or decreasing the use of a resource with a corresponsing effect on output. Examples would include adding fertilizer or applying herbicide.
2. Input-Input. This type of change involves substituting one resource for another without affecting the output. Examples would include substituting a deisel tractor for a gas tractor and renting versus purchasing machinery.
3. Output-Output. This change involves substituting one enterprise for another. For example, replacing barley with wheat or seeding cropland to pasture.

Frequently decisions will involve combinations of these three types of changes.

An important rule in budgeting is that only those cost and income items which will actually change as a result of the alternative action, should be included in calculating the payoff. The four components of the partial budget are as follows:

1. Added returns. Included here are the added returns for products sold and services rendered as a result of the proposed action.
2. Reduced costs. Involved here are the annual costs, both operating and ownership, which would no longer be incurred for the alternate action.
3. Added costs. The additional operating costs and ownership costs for new capital assets associated with this alternative are considered here.
4. Reduced returns. Included here are all returns that would no longer be received if the decision alternative is selected.

These four components can be placed in two groups as follows:

Items that add to profit	Items that subtract from profit
1. Added income________	3. Increased costs________
2. Reduced costs________	4. Reduced income________
Total (A)________	Total (B) ________

The first two parts of the budget summarize the total addition to profit, while the second two summarize the total decreases in profit. The difference between the two (A minus B) then is the net change in profit or the payoff to the decision.

How to Measure the Payoffs

As you view the alternatives listed across the top of your payoff matrix, your first question will probably be how the selection of one of these alternatives would affect your profits. A second question that you might ask is how will the alternatives affect your liquidity or cash flow? But how do we measure profitability and liquidity? We'll take a look at the issue of measuring profitability first.

Four common measures of profitability are net income, return to operator's labor and management, return to equity capital and management, and return to management. All four measures have their place and the choice of the appropriate one to use depends on the particular decision under consideration. They differ according to the costs that are considered in their calculation. The calculation of cost and return items included in the budget must be consistent with choice of the profit measure. A fifth measure relates to net cash flow.

1. Net farm income is the difference between gross farm income and gross farm expenses and has been adjusted for depreciation and changes in inventories. Thus, it represents the returns to the farmer for his labor, equity, capital, and management. (All other costs, including interest paid on borrowed capital and hired labor expenses, have been included in gross farm expenses.) Net farm income is an appropriate measure of payoffs if none of the alternative actions change the amount of unpaid labor or equity capital employed. However, if there is a change in the amounts of these resources used, then their costs need to be considered in the budget and one of the following measures should be used depending on which resources (labor or capital) are affected.

2. The return to operator's labor and management is calculated by computing an interest charge for the use of the farmer's equity capital and subtracting this amount from the net farm income. This computed charge should be based on the opportunity cost of the capital, that is, what it could earn if invested in the best alternative. This can also be expressed as the return to labor and management per hour. If the decision alternatives will influence the amount of the farmer's capital employed, but his labor input will not be affected, or if he has no alternative uses for his labor, then this measure of profit can be used.

3. Return to equity capital applies to the situation where the employment of the farmer's time will be affected. In this case an imputed charge for the farmer's labor and management is subtracted from net farm income. This imputed charge should be based on the farmer's alternative employment opportunities. This return is expressed as a percentage rate of return on the farmer's equity capital investment. This ratio can consider any changes in equity capital if the return to capital and management is calculated as a percentage of the total equity capital after adding any new investment required for the decision alternative.

4. Return to management is calculated by subtracting charges for the unpaid labor and equity capital from the net farm income. The return to management then is that amount left over to reward the decision maker for assuming the risk associated with this decision.

5. Net cash flow is usually calculated on an annual basis and measures the liquidity affects associated with each alternative action. While in the previous measures we considered both cash and non-cash income and expenses to measure profitability, this measure involves only the cash transactions. However, in addition to the income and expense items,

we must also consider the cash income from the sale of capital assets and income from outside sources. Also the cash required for family living, principal payments on debts, income taxes, and capital purchases must also be considered.

Any of the four measures of profitability would be appropriate in particular situations. The selection of which measure of profit to use depends on the effects associated with the decision alternative being considered. The costs and returns included in the budget must be consistent with the method of measuring profit. The decision maker may also be interested in looking at the cash flow or liquidity effects of the decision, as well as the profitability effects.

Budgeting Techniques Using Discounting Procedures

When the alternative actions will have income and expense effects over several years, the conventional budgeting techniques just described may not be as accurate as the budgeting techniques which employ discounting procedures. Partial and total farm budgeting do provide useful first approximations for analyzing these types of alternatives. However, the discounted cash flow techniques facilitate the evaluation of cash income and outflows over time. These more powerful techniques are helpful when the alternatives vary in the timing and amounts of investments and income. The discounted cash flow techniques are more complex and difficult to use and understand, but they do provide a more accurate analysis.

An example of a discounted cash flow technique is the net present value method. This involves estimating the cash outflow and inflow associated with the decision alternative for each year in the planning period. Then, for each year, the cash flows are discounted to the present to account for the time value of money. The discount rate would be based on the opportunity cost of the capital or a minimum acceptable rate of return. The net present value then is the sum of the discounted net cash flows for each year in the planning period. A positive net present value means that the alternative has a greater rate of return than the discount used. A negative net present value means the opposite.

References on discounted cash flow techniques are included at the end of the chapter.

Gathering the Information

Employing the budgeting procedures discussed here requires much information gathered from a variety of sources. These sources include your own farm records, your county Extension office, lenders, farm magazines, the experience of your neighbors, agricultural research and experiment stations, and others. The good manager is constantly searching for needed information. By putting information together from a variety of sources, you can develop budgeting figures that are accurate for your farm. Remember to allow for some margin of error in these figures, however, because they are still subject to some degree of uncertainty.

You should also consider the relative importance of the various cost and return items. Some cost items like fuel expenses may be of only minor significance in terms of the final accuracy of the budget, while others are of major importance. Your time in gathering information about these estimates should be allocated accordingly. The greater the size of the item, the more influence it will have on the budget total, and the greater the need that it be accurately determined. For example, a 5% error in the quantity of feed consumed may change costs by $1,000, whereas a 50% error in the cost of insurance may affect the total by only $100.

AN EXAMPLE PAYOFF MATRIX

Harry Corngrower has the opportunity to purchase an irrigation system for part of the land he owns for $50,000. He also has the opportunity to purchase 100 acres of land for dryland farming for $50,000. He can borrow the money for either investment but he cannot do both. He believes that with normal or above normal rainfall the additional land would be a better investment but that with below normal rainfall in the future, then the irrigation system would be a better investment. Let's prepare some budgets and a payoff matrix for Harry's decision. Harry's use of equity capital and his own labor will be the same regardless of which alternative he chooses, so we'll use net farm income as our measure of profit. A partial budget for each alternative will be a satisfactory method of analysis. A 10 year planning period will be used for each alternative.

First, we'll compute the change in net farm income if Harry purchases 100 acres of land on which to grow corn without irrigation. We'll need to know the yield to be expected under each level of rainfall, the price to be received and the costs for growing and harvesting the corn. The land will not depreciate but we need to consider the interest charges which at 9% will be $4,500 per year.

Harry believes that with normal rainfall the corn yield on the purchased land will be 70 bushels per acre. With high rainfall, the yield will be 80 bushels, but with low rainfall it will be 50 bushels. He expects the price of corn to be $2.10 per bushel net of hauling and drying costs.

With normal rainfall and a 70 bushel yield, variable costs for seed, fertilizer, fuel, repairs, etc. based on his current experience, are expected to be $70 per acre. Hired labor costs are expected to be $15. Harry has enough equipment to handle the additional 100 acres. Therefore, he will not have additional depreciation and interest for equipment. Corn will be custom dried and sold at harvest so no additional drying or storage facilities are needed.

If growing season rainfall is high, additional nitrogen fertilizer ($4.00/acre) will be used. If the weather is dry, less nitrogen ($6.00/acre) will be used. All other costs would be the same regardless of whether the rainfall is high, normal or low.

Costs and returns for the additional 100 acres are summarized below for the three levels of rainfall:

	Rainfall		
	Low ($)	Normal ($)	High ($)
Added income	10,500	14,700	16,800
Added costs			
Operating	6,400	7,000	7,400
Hired labor	1,500	1,500	1,500
Interest	4,500	4,500	4,500
Taxes	1,000	1,000	1,000
Total	13,400	14,000	14,400
Change in net income	-2,900	700	2,400

The irrigation alternative has a 50,000 investment for the irrigation system and a well for 100 acres. This system is expected to be useful for longer than the 10 year planning period. Harry believes that a $20,000 salvage value at the end of 10 years would be reasonable. Therefore, the depreciation is:

$$\frac{50,000 - 20,000}{10} = \$3,000 \text{ per year}$$

The interest charge with a 9% rate is:

$$\frac{50,000 + 20,000}{2} \times .09 = \$3,150 \text{ per year}$$

Harry expects that with the irrigation system his corn yield would be 110 bushels per acre. His current yield is the same as the yield he expects on the land he is considering for purchase. Therefore, the irrigation system is expected to add 40 bushels to yield with normal rainfall, 60 bushels with low rainfall, and 30 bushels with high rainfall.

The only significant operating cost increases with the irrigation system will be electricity, repairs, additional fertilizer, and some labor for operating the irrigation system. Harry expects to use more nitrogen per acre on irrigated corn than he would on dryland with normal rainfall. Labor is expected to be an additional hour per acre. Power and repair costs are expected to be $10 per acre with normal rainfall but more with low rainfall and less with high rainfall.

	Rainfall		
	Low	Normal	High
	($)	($)	($)
Added Income	12,600	8,400	6,300
Added Costs			
Fertilizer	1,800	1,200	800
Hired Labor	300	300	300
Power and repairs	1,200	1,000	800
Taxes and insurance	200	200	200
Depreciation	3,000	3,000	3,000
Interest	3,150	3,150	3,150
Total	9,650	8,850	8,250
Change in net income	2,950	-450	-1,950

Table 3-2. Payoff Matrix for Irrigation System vs. Land Purchase Decision.

Events	Actions: Purchase irrigation system	Actions: Purchase 100 acres of land
	--Payoffs (Net Income)--	
Low rainfall	2,950	-2,900
Normal rainfall	-450	700
High rainfall	-1,950	2,400

Table 3-2 is the payoff matrix for this decision problem of whether to purchase an irrigation system or an additional 100 acres of land. The payoffs range from -$1,950 to +$2,950 for the irrigation alternative and from -$2,900 to +$2,400 for land purchase. Thus, the matrix summarizes much of the important information that Harry needs to consider for this decision choice. Harry may also have information regarding the occurance of the rainfall events. As is discussed in the following chapter this information can be summarized as probability estimates and used in combination with this payoff matrix to help Harry make his decision.

SUMMARY REMARKS

The use of the payoff matrix approach to decision making has several advantages. The payoff matrix approach provides you with a framework for specifying the various components of a decision. It breaks a decision down according to what <u>can</u> be controlled (the alternative action) and what <u>can't</u> be controlled (the possible event). The organization of the decision problem helps you to focus on your most promising alternative actions and on the events that are most likely to significantly affect the outcome of your decision. Within this framework then you have a guide for budgeting out the net payoffs associated with each action and event combination.

The difficulty in applying the payoff matrix concept lies in narrowing down your alternative actions and the possible events to those that are most important to the decision problem you face. However, regardless of how you make the decision, you must go through this same process. The difference is that the payoff matrix approach gives you a clear record of your alternative actions, the events you consider most significant, and the budgets you prepare in arriving at your decision. The payoff matrix then helps to insure that your decisions are based on the best possible information and are consistent with the objectives you have established for your farm operation.

SOME BUDGETING REFERENCES

Quenemoen, M. E. Complete and Partial Budgets for Farm and Ranch Decisions. Montana State University Coop. Ext. Service Bul. 1066, Jan. 1975.

Fellows, I.F., ed. Budgeting: A Tool of Research and Extension in Agricultural Economics. University of Connecticut Agr. Exp. Sta. Bul. 357, April 1962.

Aplin, R. D., G. L. Casler, and C. P. Francis. Capital Investment Analysis Using Discounted Cash Flows. 2nd ed. Columbus, Ohio: Grid, 1977.

Doran, S. M. Preparing a Farm Budget. Washington State University Coop. Ext. Service EM3569, July 1972.

Thomas, K., R. N. Weigle, and R. Hawkins. Where Do I Want to Be? Appraising Your Long-Range Farm Opportunities. University of Wisconsin Coop. Ext., North Central Reg. Ext. Pub. 34-3, Jan. 1973.

Appendix

DECISION TREES

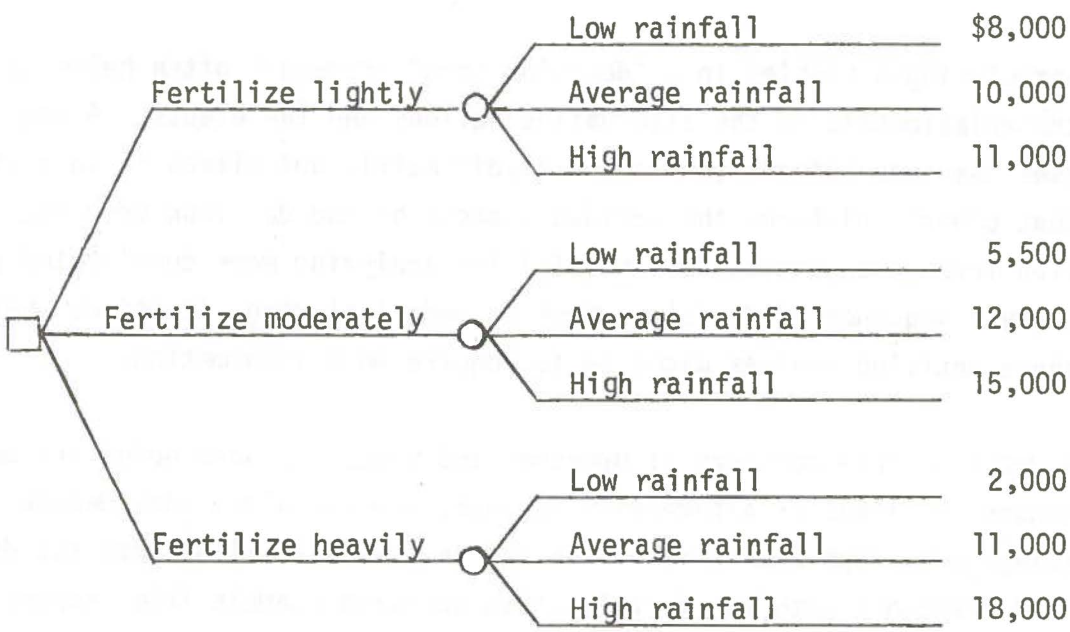
Structuring a problem in a "decision tree" framework often helps to clarify the relationship of the alternative actions and the events. A decision tree uses the same information as the payoff matrix but places it in a structure that clearly pictures the various aspects of the decision problem. Decision trees are particularly helpful for analyzing more complicated problems where a sequence of decisions must be made including situations where one of these decision choices might be to acquire more information.

A decision tree consists of branches and nodes. Square nodes are used to denote decisions or alternative actions, and circular nodes denote the things that depend on chance, the events. We will illustrate the decision tree framework with the fertilization decision example from Chapter 2.

Recall that the payoff matrix for the fertilization decision looked like this:

	Actions		
Events	A_1 Fertilize lightly	A_2 Fertilize moderately	A_3 Fertilize heavily
	--Net return ($) from 400 acres--		
E_1 - low rainfall	8,000	5,500	2,000
E_2 - average rainfall	10,000	12,000	11,000
E_3 - high rainfall	11,000	15,000	18,000

The decision tree for this fertilization problem appears as follows:



The decision tree is drawn in chronological sequence from left to right with the alternative acts (level of fertilizer application) branching from the decision node denoted by a square and the events (level of rainfall) branching from event or chance nodes denoted by circles. The dollar payoffs are indicated at the terminal branches. At the decision node, it is the decision-maker's choice whether to go down the "lightly," "moderately," or "heavily" branch. For each of these three action branches there are three event branches corresponding to "low," "average," or "high" rainfall.

This decision tree approach can be used to represent more complicated situations. Suppose that the decision maker has to make two fertilizer decisions, one prior to planting and the other a top dressing decision after emergence of the crop. These could be represented in the decision tree with intervening rainfall or weather events. It might also be possible for the manager to purchase a long-range weather forecast. The "purchase" or "no-purchase" alternatives could be represented as a decision node with an event node representing the outcome of the forecast.

As further complexities are added to the decision problem, the decision tree can become a "bushy mess." When the number of nodes, alternative actions, and number of events multiply, the tree explodes rapidly. It is best to begin with a rather coarse tree specifying only the major branches; checking and lopping off the inferior actions and insignificant events; developing the unlopped branches in further detail; and repeating the cycle.

Drawing an adequate decision tree (or preparing a realistic payoff matrix) is not often easy and first attempts can be frustrating. It is even more difficult when the decision problem is not well specified before beginning with the analysis. The advantage of the decision tree approach is that it allows the components of the decision problem to be laid out, showing the chronological interaction of alternative actions and events.

Chapter 4

USING PROBABILITIES

A probability is a number that measures the likelihood or chance that a particular event will occur. An event is something that might happen in the future over which you have no control. This number that represents a probability can be zero through one, inclusive. Zero means there is no chance that the event will happen, and one means it is certain to happen. Also, the sum of the probabilities of all the possible events that can occur in a given situation must add to one.

Probabilities can be expressed as fractions, such as 1/10 or 1/5, or as decimal fractions, such as 0.1 or 0.2. Percentages, such as 10 percent and 20 percent are also commonly used. These are equivalent ways of saying the same thing.

THE THREE TYPES OF PROBABILITIES

There are three different types of probabilities based on the way they are estimated or derived.

Empirical Probabilities

This type of probability is based on the frequencies of empirical observations. An example based on past rainfall data will illustrate. Assume that rainfall in September and October is of interest as a means of anticipating the chance of getting a vigorous stand of winter wheat. The answer could affect pasture grazing plans and other decisions. Past totals can be grouped into ranges (class intervals) to estimate the probability (or frequency) of different rainfall levels. Records for twenty years at a weather observation point in North Central Oklahoma provide the frequencies shown in Table 4-1.

Table 4-1. Rainfall Amounts for September Through October, North Central Oklahoma

Rainfall Amount	Number of Years	Probability Based on Frequency
0-1.5	4	4/20
1.51- 3.0	3	3/20
3.01- 4.5	2	2/20
4.51- 6.0	1	1/20
6.01- 7.5	4	4/20
7.51- 9.0	3	3/20
9.01-10.5	1	1/20
10.51-12.0	1	1/20
12.01-13.5	0	0
13.01-15.0	1	1/20
Total	20	1

Using Table 4-1, a farmer could determine that the chance of getting a disasterous 0 to 1.5 inches is 4/20 or .2. The critical range of 0 to 3 inches has a chance of 7/20 (4/20 + 3/20). On the other end of the scale, rainfall above 7.5 inches would probably delay planting and temporarily damage crop prospects. The chance of less than 3 inches (7/20) plus the chance of rainfall above 7.5 inches (3/20 + 1/20 + 1/20 + 1/20 = 6/20) gives a 13/20 chance of some problems with the wheat crop during the fall. (Fortunately crop production records for North Central Oklahoma show more success than these figures may indicate. The grain crop is fairly sure and stable.)

Empirical probabilities based on past data may be quite useful for some management phenomena but less useful for others. For example, past rainfall data may be a good guide to future rainfall while wheat price probabilities based on historical data may be a poor guide for the future.

Deductive Probabilities

The frequency approach to estimating probabilities is only one way. A second approach is a deductive approach. For example, if one has a normal coin with a head and tail, it is not really necessary to use a frequency approach to decide the expected frequency of heads and tails in a certain number of tosses. The chance of a head is one-half. The same is true of a roulette wheel which has 36 red and black numbers and two green numbers. The chance of a red number is 18/38th and so on.

One could build frequency data using a vase containing 3 red balls and 7 black balls to determine that the frequency, after sufficient draws with replacement of balls after each draw, is 3 red balls to 7 black balls. However, this can be obtained more simply by deduction assuming that the balls are randomly taken from the vase. Unfortunately, most of the phenomena which must be considered in farm decision-making are not subject to such logical deduction.

Subjective Probabilities

The third concept of probability is called subjective probability. Subjective probabilities measure the decision-maker's strength of conviction about the chance of occurrence of a particular future event. These are estimates based on his personal beliefs about these events. Thus, they are sometimes called "personal" probabilities.

In estimating these probabilities, we assume that the rational decision-maker examines his own experience, the data that are available, and consults whomever he can, as time and money allow. Personal or subjective probabilities allow the decision-maker to summarize everything he knows about the occurrence of a future event or situation. The probabilities summarize this information in convenient and easy-to-work-with numbers.

There is really no logical difference between probabilities assigned subjectively and "objective probabilities" discussed earlier, particularly ones based on frequency. In the frequency case, certain underlying assumptions exist. For example, the decision-maker must decide whether the past frequencies reflect the future and whether there are enough observations. In effect, he had to consider the observations using his own judgement, resulting in a subjective evaluation. The subjective probability school of thought, then, would argue that all probabilities are subjective and that it is not so strange that a decision-maker would presume to estimate the probabilities for his real-life decision problem.

It is quite possible that two reasonable persons will assign different probabilities to the same event. However, this doesn't mean that these probabilities are arbitrarily assigned. It does mean that the persons have different information and are using different experiences for interpreting this information. If two reasonable people have roughly the same experience and are given the same information regarding a particular event, they will both assign it the same probability.

In developing personal probability estimates, the decision-maker should use all the information he can obtain from a variety of sources, including what's happened in the past. To this, he applies his own intuitive judgement to come up with his probabilities. These probability estimates should not be cast in concrete. They should change as the quantity and quality of information available to the decision-maker changes. Thus, as time passes, the decision-maker needs to continue to review the situation, collect more information, and revise his probabilities to reflect his new knowledge.

The remainder of this chapter discusses some of the procedures and rules for estimating probabilities and also explains how they can be used to generate management information.

ESTIMATING SUBJECTIVE PROBABILITIES

Learning to estimate and use probabilities is important to the application of decision theory. Thus, several examples are provided of procedures and applications.

Suppose we are considering the price of wheat at Kansas City at harvest time next year. To put this in probability terms, the distribution of prices must be so structured that the sum of the probabilities adds to 1. Therefore, we must think of the lowest and highest prices we would expect to occur and, of course, all of the prices in between. If we did this by 1 cent intervals, we would have a large number of possible prices, perhaps all the way from $2.00 to $5.00, or about 300 probabilities. Usually we wouldn't need this much detail so price ranges are used. One possibility would be ranges of 25 cents. To make the illustration a little less cumberson, let's make the high $4.50 and the low $2.50.

The subjective probabilities listed are those of one decision-maker. Yours could be quite different. The important point right now is that the sum of the probabilities must add to 1.0. If the decision-maker believes that the price might fall outside the $2.50 to $4.50 range, he must extend the limits and redistribute his probabilities so that they continue to add to 1.0.

Wheat Price	Subjective Probability
$2.50 - 2.75	0.1
$2.75 - 3.00	0.1
$3.00 - 3.25	0.1
$3.25 - 3.50	0.2
$3.50 - 3.75	0.2
$3.75 - 4.00	0.1
$4.00 - 4.25	0.1
$4.25 - 4.50	0.1
	1.0

Subjective probabilities really measure a person's strength of conviction that an uncertain event will occur. Therefore, your subjective probabilities about a situation could be quite different than mine and yet they could be just as good or even better than mine. But that doesn't mean that someone couldn't teach both of us to make better estimates of our subjective probabilities. One way to improve probability estimates is to gather more information. But first, we'll discuss the rules for estimating probabilities and then illustrate some methods for making the estimates.

Rules for Probability Estimation

The rules for defining and computing probabilities force the decision-maker to be consistent. To be called probabilities, the numerical estimates assigned to the various events must conform to two rules. The first rule is that the probability for a particular event is a number between 0 and 1, inclusively. A couple of important observations can be made regarding this rule. First, an event that is certain to occur will have a probability of 1. For example, the event "wheat prices will rise, fall, or remain unchanged" is certain and has a probability of 1. At the other extreme, the probability for an impossible event is 0. In other words, it is impossible that wheat prices next week can be $25 per bushel, and the probability assigned to this event would be 0. Before going to a second rule, we must consider two special relationships between events that are important to estimating probabilities.

The first way that two events can be related is that the occurrence of one event precludes the occurrence of the other. For example, if the coin lands with head showing it cannot show tail. Both events cannot occur on one toss. This is the same as saying that the two events are mutually exclusive. Next month's average wheat price is an uncertain outcome that may range from as low as $2.00 per bushel to a high of $5.00 per bushel. Any wheat price between these extremes is a possible event, however since there will be just one average price, all the possibilities are mutually exclusive events.

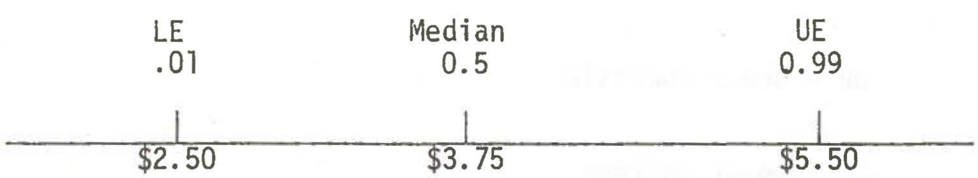
The next relationship between two events is that one of them must occur. In the coin toss example with the events, head and tail, at least one of the events is certain to occur. This relationship between events is described as collectively exhaustive. Back to our next month's average wheat price example, if we have defined our high and low prices such that there is no way that next month's price can be below the low or above the high, then all of the possibilities between these extremes are collectively exhaustive.

The second rule then for the estimation of probabilities is that the sum of the probabilities assigned to a set of mutually exclusive and collectively exhaustive events must be 1. A sum less than 1 would mean that the events are not collectively exhaustive and a sum greater than 1 would indicate that more than one event could occur. In other words, they are not mutually exclusive.

We will illustrate three methods of estimating subjective probabilities using a wheat price example. A fourth method, triangular probability distribution, is described in an appendix to this chapter.

Estimating Probabilities Using the Cumulative Distribution Approach

To use this first method, you would be asked (or ask yourself) what is the median wheat price to occur at some time of interest in the future. The price you choose should be such that there is an equal likelihood that the price will be above as below this level. In other words, the probability of the price being above this level should be 0.5 and the probability of the price being below this level should also be 0.5. We call this the median price. Suppose you choose a median price of $3.75. Now you ask yourself the lowest and highest that the wheat price might be. Actually, we'll allow you a 1 percent chance (.01 probability) that the price will be below and above your extremes. Suppose you decide $2.50 (bumper crop and little foreign demand) and $5.50 (poor U.S. crop and big foreign demand). These prices would be entered on a probability scale as follows:



After picking up your high (UE) and low (LE) price, we'll allow you to change your median if you wish. Keep in mind that the median does not need to be halfway between the high and low. Let's assume that you leave the median price at $3.75. We call this your "judgemental midpoint" for wheat price next July. You should believe the price to be just as likely to be above $3.75 as below $3.75. If not, the $3.75 should be adjusted up or down.

Next we ask you to consider the segment between $2.50 and $3.75. What is your "judgemental midpoint" here? That is, what is the value above and below which you believe that the price is equally likely to be (assuming, of course, that the price is below $3.75). Suppose you choose $3.25. Next we ask a similar question about the segment between $3.75 and $5.50 and you choose $4.50 as your judgemental midpoint. This allows us to complete our "probability line".

LE	LQ	M	UQ	UE
0.01	0.25	0.50	0.75	0.99
$2.50	$3.25	$3.75	$4.50	$5.50

The letters above the line are defined as follows:

LE = Lower extreme

LQ = Lower quartile

M = Median

UP = Upper quartile

UE = Upper extreme

In tabular form, this information could appear as follows:

Wheat Price (P)	Probability that price will be less than P
$2.50 (lower extreme)	0.01
3.25 (lower quartile)	0.25
3.75 (median)	0.50
4.50 (upper quartile)	0.75
5.50 (upper extreme)	0.99

This table shows that you believe that there is a 1 percent chance that the wheat price will be below $2.50, 25 percent chance that it will be below $3.25, 50 percent chance below $3.75, 75 percent chance below $4.50, and 99 percent chance below $5.50. In slightly different terms, you believe there is a 1 percent chance of the price being above $5.50, 25 percent chance above $4.50, and 50 percent chance above $3.75.

Your subjective probabilities can be shown in the more usual probability table:

Wheat Price	Subjective Probability
Below $2.50	0.01
$2.50 - 3.25	0.24
3.25 - 3.75	0.25
3.75 - 4.50	0.25
4.50 - 5.50	0.24
Above 5.50	0.01
	1.00

This table shows your subjective probabilities for wheat prices within certain ranges. These are not fixed price ranges, but ranges representing your quartile and upper and lower extremes. For decision purposes you might prefer to have the data in a different form, for example, each group representing an equal range of prices.

Using the data from your probability line, we can prepare a graph showing the cumulative distribution of your wheat price probabilities (Figure 4-1).

By joining the five points we can construct a continuous cumulative distribution of your subjective probabilities for wheat prices. We could then read from the graph the probabilities of wheat prices for any kind of price groupings in which we were interested, for example, 10 cent or 25 cent ranges. This is done by subtracting from the cumulative probability for the top of a desired range the cumulative probability for the bottom of the range (or top of the previous range).

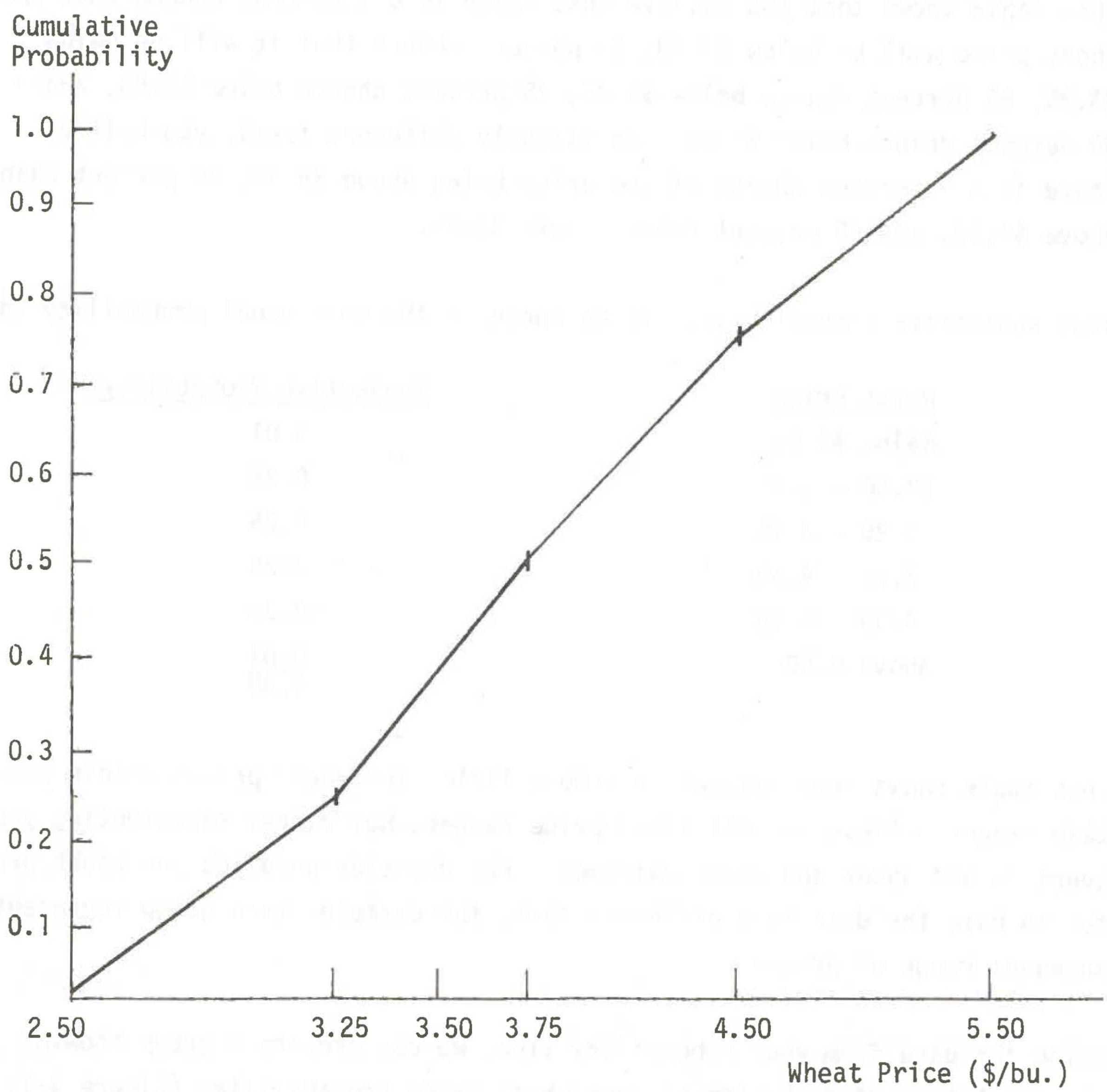


Figure 4-1. Cumulative Subjective Probabilities for the Price of Wheat

Estimating Probabilities With "Conviction Weights"

Now a second method will be illustrated by which your subjective probabilities for wheat price (or any other uncertain event) could be estimated or assessed. This method uses numerical weights measuring strengths of conviction. To use this method, the uncertain event is divided into logical ranges. For the wheat price problem we'll use ranges of 25 cents per bushel as shown in the first column below.

The decision-maker then enters in the second column a number zero through 100 to indicate his belief that the wheat price will fall in each of the ranges. If he believes that the price will not be in any one of the ranges he gives that range a zero. If he is sure the price will fall in one of the ranges, he would enter a 100 for this range and enter a zero for all other ranges. In our example, the price projector believes that there is no chance of the price being either below \$2.75 or above \$4.75 so he entered zeros. He has also entered numbers in the other categories in relation to his strength of conviction that prices will fall in these ranges. Subjective probabilities are then calculated by dividing the sum of the numbers into the number in each range. In this case we have divided 452 into each number and entered the probabilities in the last column. The sum of the probabilities should be (and is) 1.0.

With this approach before assigning his ratings, zero through 100, our decision-maker should consider the general shape that the distribution should assume. Will it be normal, skewed, or uniform? The choice should recognize the nature of the variation in the phenomenon for which probabilities are being developed. These shapes are illustrated in Figure 4-2.

For a normal distribution, higher ratings are assigned to the "middle" events and lower ratings towards the "higher" and "lower" events. For a skewed distribution, assign the highest ratings to the events to the right or left of the middle. Assign the same ratings to each event for a uniform distribution.

Wheat Price ($ per bu.)	Your conviction that the price will be in the given range (0 through 100)	Subjective Probabilities
Less than 2.50	0	0
2.50 - 2.75	0	0
2.75 - 3.00	13	.03
3.00 - 3.25	38	.08
3.25 - 3.50	75	.17
3.50 - 3.75	100	.22
3.75 - 4.00	100	.22
4.00 - 4.25	75	.17
4.25 - 4.50	38	.08
4.50 - 4.75	13	.03
4.75 - 5.00	0	0
5.00 - 5.25	0	0
5.25 - 5.50	0	0
Over 5.50	0	0
	452	1.00

Direct Estimation of Probabilities

A third method of estimating subjective probabilities is to ask the decision-maker to directly state his probabilities, either as probabilities or in percentage terms. We'll do this for the wheat price problem but in 50 cent ranges. In this method the decision-maker must enter his probabilities so that they add to 1.0. A trial and error process is followed until he is satisfied with the relationships among the various individual probabilities and they also sum to one.

You will note that we have specified the 50 cent ranges so that they centered on 50 cents and $1.00 rather than on 25 cent and 75 cent points. In effect, this specification may focus attention on the midpoints such as $3.00, $3.50, etc.

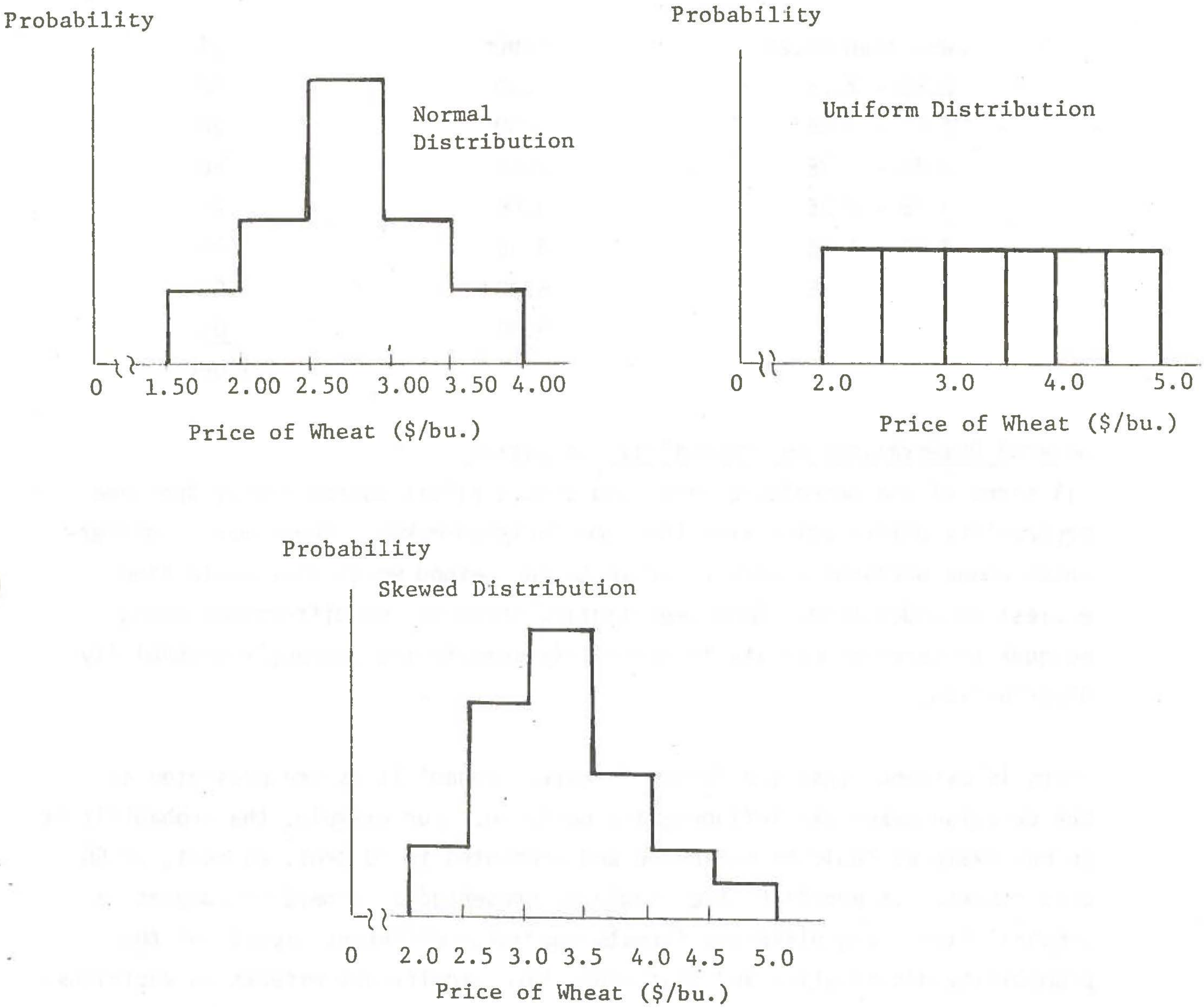


Figure 4-2. Examples of Shapes of Probability Distributions

Wheat Price ($ per bu.)	Midpoint	Subjective Probability
Less than $2.25	2.00	.01
2.25 - 2.75	2.50	.02
2.75 - 3.25	3.00	.20
3.25 - 3.75	3.50	.50
3.75 - 4.25	4.00	.20
4.25 - 4.75	4.50	.04
4.75 - 5.25	5.00	.02
Over 5.75	5.50	.01
		1.00

General Observations on Probability Estimation

All three of the methods we have used should elicit approximately the same probability distribution from the same decision-maker. There may be differences among decision-makers relative to the method which they would find easiest to understand. More importantly, there may be differences among methods in terms of ability to accurately specify the subject's probability distribution.

There is evidence that the format in which probabilities are presented to the decision-maker can influence the decision. For example, the probabilities in our examples could be estimated and presented in 10 cent, 25 cent, or 50 cent ranges. In addition, they could be presented as simple or cumulative probabilities. The different formats emphasize different aspects of the probability distribution and thus could have significant effects on decisions.

The sizes of the intervals or ranges used by the decision-maker to specify his objective probabilities could significantly affect the distribution. It may be helpful to specify such ranges in a way consistent with the thinking of the decision-maker. For example, a wheat grower may find it easier to think of wheat prices as discrete occurrences such as $3.25, $3.50, $3.75, and $4.00 rather than in ranges such as $3.25 to $3.50, $3.50 to $3.75, etc. In such a situation a good procedure may be to explain to the decision-maker that a price of \$3.25 really means the range from \$3.12½ to \$3.37½, etc. A corn grower might think in terms of 10 cent prices, that is, \$2.50, \$2.60, \$2.70, etc. Therefore, the categories used in estimating his corn price probability distribution might be in terms of those just listed, with the understanding that each point includes 5 cents above and below the price indicated.

Similarly, a corn grower familiar with yields around 100 bushels per acre might think in terms of five bushel increments while a dryland wheat grower with yields around 30 bushels might think in terms of one or two bushel increments. Structuring the probability estimation table in increments meaningful to the decision-maker should help in more correctly estimating his subjective probability distribution.

Now to review, here are some cautions to be observed in the estimation of subjective probabilities:

1. In deriving your estimates of probabilities of future events, be as objective as possible. Don't be influenced by what you <u>hope</u> will happen.

2. Consider the full range of the possible events. Don't overlook the extremely low, or high, events that could occur.

3. Be ready to review probabilities as soon as more information becomes available and aggressively seek out this information.

4. Ask yourself whether your distributions are consistent with your uncertainty. Is the shape of your distribution relatively flat or is it peaked?

5. Check to be sure that you have satisfied the rules for calculating probabilities (are the events collectively exhaustive and mutually exclusive?).

Estimating Joint Probabilities

Two events are independent if the occurrences of one is not affected by the occurrences of the other. For example, if two coins are tossed fairly, one at a time, the occurrence of a head or tail for one coin is not affected by the occurrence on the other coins, and vice versa. Occurrence of a low wheat price nationally is not affected by local crop production in a single county. Thus, wheat price and local weather are relatively independent. Wheat yield and barley yield on the same farm are not independent. Such observations are important in developing and using probabilities in decision-making.

The joint probabilities (chance of the two events occurring together) of two independent events can be calculated by multiplying the independent probabilities. For example, suppose we have a set of wheat price and a set of wheat yield subjective probabilities for a wheat grower.

Prices		Yield	
Level ($)	Probability	Level (Bu./acre)	Probability
3.50	0.3	25	0.3
4.00	0.5	30	0.6
4.50	0.2	35	0.1

Assuming these two probability distributions are independent, there are 9 possible combinations of prices and yields. (Prices and yields are likely not independent if we think of U.S. average prices, but could be independent for the individual grower.)

The combinations, that is, the gross incomes, and their probabilities are given below. For convenience, the data have been arranged in order of increasing gross income. If the $120 is a critical value to the farmer for meeting living needs and expenses, the sum of the joint probabilities for gross incomes below this level would provide important information.

Price ($)	Yield (bu.)	Gross ($)	Probabilities Price	Yield	Joint
3.50	25	87.50	0.3	0.3	0.09
4.00	25	100.00	0.5	0.3	0.15
3.50	30	105.00	0.3	0.6	0.18
4.50	25	112.50	0.2	0.3	0.06
4.00	30	120.00	0.5	0.6	0.30
3.50	35	122.50	0.3	0.1	0.03
4.50	30	135.00	0.2	0.6	0.12
4.00	35	140.00	0.5	0.1	0.05
4.50	35	157.50	0.2	0.1	0.02
					1.00

What if the events are not independent? Two events are not independent if the occurrence of one of the events affects the probability of the occurence of the second. For example, the yields of dryland crops on a particular farm are all affected by the rainfall and weather conditions. In this case, the probabilities of the joint events must be estimated directly for the combination of events. The farmer's probabilities for crop yields might look something like this:

Crop yields Wheat	Barley	Probabilities
Low	Low	0.40
High	Low	0.04
Low	High	0.06
High	High	0.50
		1.00

USING PROBABILITIES TO GENERATE MANAGEMENT INFORMATION

This section discusses additional pieces of information that can be generated from the probabilities you have estimated. These are the expected value of the probability distribution and the cumulative probabilities.

The Expected Value

Now that we have estimated the probabilities for a set of possible events, we can compute an additional piece of management information, the expected value of that probability distribution. The expected value is an average, however, it is computed differently than the simple arithmetic average with which you may be familiar. The expected value is a weighted average of the set of events, weighted according to each event's probability of occurring.

To calculate expected prices from our probability tables in which prices are stated as ranges, we would simplify by using midpoints of the ranges. The probability is multiplied by the midpoints and the result is totaled for all midpoints. The end points (less than and more than) would be arbitrarily set at some level below and above, or perhaps at the end points. We have set them at $2.00 and $5.50. The expected price for our previous example is $3.555 (see next page).

The expected value of your probability distribution of wheat prices is the "average" you would expect to receive if you sold at that time. If you could sell your wheat a large number of times under these same circumstances, the expected value would be the same as the average of all the prices you received. The price you received for any one sale may be higher or lower, but over several sales the average price would equal the expected values.

Remember the expected value is an additional piece of information that can be used in conjunction with the probability distribution, but not to replace it. Normal and uniform probability distributions would have the same expected value, but represent quite different situations regarding the uncertainty of the events.

Wheat Prices: Range	Wheat Prices: Midpoint	Subjective Probability	Products
Less than 2.25	2.00	.01	.02
2.25 - 2.75	2.50	.02	.05
2.75 - 3.25	3.00	.20	.60
3.25 - 3.75	3.50	.50	1.75
3.75 - 4.25	4.00	.20	.80
4.25 - 4.75	4.50	.04	.18
4.75 - 5.25	5.00	.02	.10
Over 5.25	5.50	.01	.055
		Expected value	$3.555

Cumulative Probabilities

Quite often, farmers will set price goals that they would like to achieve when marketing their crops. A logical question to ask is "what is the probability of the price being lower than the desired price goal?". The answer to this question is a cumulative probability.

Suppose I am interested in figuring what the probability is of the price being below a price goal which I would like to receive. I have estimated the probability of the price being in several intervals as follows:

Price	Probability
$2.50 to 2.75	.10
2.75 to 3.00	.15
3.00 to 3.25	.25
3.25 to 3.50	.20
3.50 to 3.75	.15
3.75 to 4.00	.10
4.00 to 4.25	.05
	1.00

My price goal is $3.00. To figure the probability of being below $3.00, I just add the probabilities of those prices below $3.00: .10 + .15 = .25. The odds are about 1 in 4 that the price will be below my price goal of $3.00. The probability of .25 is termed a "cumulative" probability because the probability of several events have been added together.

The successive addition of probabilities of mutually exclusive events for a given situation forms a cumulative probability distribution. To calculate a cumulative distribution begin with the probability of the lowest valued event and add the probability of the next highest valued event to it. Continue adding probabilities one event at a time until the probabilities of all events have been added. The cumulative probability for the last event should be one.

Suppose we had probability distribution for price such as the one just presented. We would construct the cumulative distribution as follows:

Price	Probability	Cumulative Distribution
$2.50 to 2.75	.10	.10
2.75 to 3.00	.15	.25
3.00 to 3.25	.25	.50
3.25 to 3.50	.20	.70
3.50 to 3.75	.15	.85
3.75 to 4.00	.10	.95
4.00 to 4.25	.05	1.00
	1.00	

The advantage of using this cumulative distribution is that the probability of the price being below any given level can be read directly.

SUMMARY REMARKS

Subjective or personal probabilities allow you to summarize everything you have read, seen, and heard about a future event or situation in the form of easy-to-work with numbers. These probabilities can be estimated using different approaches. Direct estimation is difficult where more than three events are possible. The cumulative distribution approach, although somewhat complicated, offers possibilities when the events are continuous rather than discrete. The procedure of assigning weights which measure the strength of conviction that the event will occur has been tested with success with farmers. Additional testing is needed to compare these alternative approaches to probability estimation and determine how well they reflect the decision-maker's true beliefs.

These estimated probabilities can be used to generate additional information for making decisions, such as the expected value and cumulative probabilities. Both should be carefully interpreted in the context of your attitudes about risk taking, the subject of the next chapter.

Appendix

TRIANGULAR DISTRIBUTIONS

A convenient alternative to the three methods described for estimating subjective probability distributions is the triangular distribution. Only three numbers are necessary to specify the distribution: the minimum, most likely, and maximum events.

In the example (Figure 4-3) the "lowest possible" wheat yield is 15 bushels, the "highest possible" yield is 55, and the "most likely" wheat yield is 30. If these three values can be supplied, the distribution is determined.

The triangular distribution offers a great deal of flexibility in the shape of the distribution. It can be skewed, or it can be symmetrical like a normal distribution. The primary advantage, however, is the ease with which it can be elicited by the decision-maker.

We will use prices to illustrate how the probabilities for various events can be calculated using the triangular distribution and a formula. The decision-maker would be asked to state the lowest, most likely and highest wheat prices he would expect to occur. Suppose he says $2.50, $3.50 and

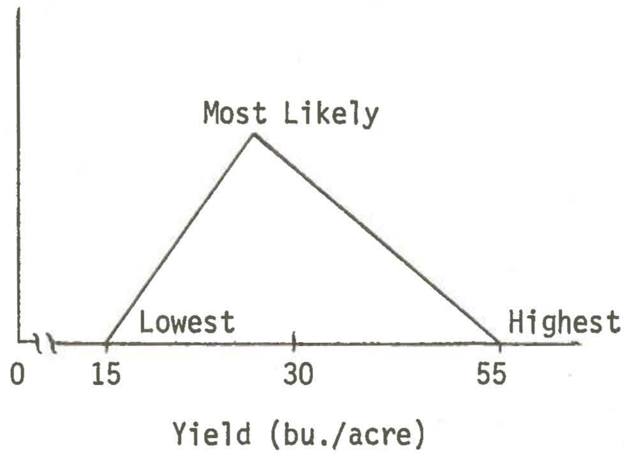


Figure 4-3. A Triangular Distribution of Crop Yields.

$4.50. Note that this distribution is symmetrical; there is the same chance of the price being above as below the most likely price. Triangular distribution functions can be symmetrical, but they can also be skewed in either direction. The shape will depend upon the decision-maker's most likely value in relation to the minimum and maximum values he would expect.

Suppose our decision-maker wants to compute the probabilities of the prices being in each of the four 50¢ ranges between $2.50 and $4.50 using the triangular distribution formula for computing a cumulative distribution. The formula is:

$$CP = 1 - \frac{X^2}{M}$$

where CP = cumulative probability

X = values between 0 and 1, which represent, in this case, the range of prices from $2.50 to $4.50.

M = the most likely price, in this case, 0.5 represents $3.50, the midpoint of the $2.50 to $4.50 range.

This formula is used for values of X less than M. For values of X greater than M, the formula is:

$$CP = \frac{(1-X)^2}{(1-M)}$$

For values of X = M, either formula can be used. In this case also, M = 0.5.

Values of X are assigned to each price. For example, $3.00 is 1/4 the range of prices so it is assigned a value of 0.25, etc. The X values are then substituted into the formulas to find the cumulative probabilities:

$$\text{For } X = .25;\ 1 - \frac{(.25)^2}{.5} = \frac{.0625}{.5} = 1 - .125 = .875$$

Thus, the probability of the price being greater than $3.00 is 0.875. The remainder of the cumulative probabilities are shown below:

Price	Values of X	Subjective probability of price being greater than X
2.50	0.0	1.000
3.00	0.25	.875
3.50	0.50	.500
4.00	0.75	.125
4.50	1.0	0.0

The probabilities of the price being in each of the 50¢ ranges (as calculated from the triangular distribution function) are calculated from the cumulative function by subtraction:

Price	Subjective Probability
$2.50 - $3.00	0.125
3.00 - 3.50	0.375
3.50 - 4.00	0.375
4.00 - 4.50	0.125

The decision-maker could then use this subjective probability distribution of prices as it stands or modify the distribution if he doesn't believe that it represents his judgement about prices.

Now let's consider a triangular distribution in which the most likely value is not the midpoint between the low and the high values. Suppose a grower believes his most likely crop yield is 40 bushels but it could be as high as 50 or as low as 25. The yields for 5 bushel increments and the corresponding X values are shown below:

Yield	Values of X	Subjective probability of yield being greater than X
25	0.0	1.00
30	.2	.93
35	.4	.73
40 (M)	.6	.40
45	.8	.10
50	1.0	0.00

Using the triangular distribution function, the cumulative subjective probability distribution can be calculated. For a value of X = .2, the calculations are:

$$1 - \frac{(.2)^2}{.6} = 1 - \frac{.04}{.6} = 1 - .07 = .93$$

The probabilities of the wheat yield falling in each 5 bushel ranges are:

Wheat Yield	Subjective Probability
25-30	.07
30-35	.20
35-40	.33
40-45	.30
45-50	.10

The triangular distribution function has the advantage that the decision-maker does not need to think in detail about the entire probability distribution. He needs only to specify the most likely and lowest and highest values that he believes could occur. A few rather simple calculations using the triangular distribution formulas allow the computation of the probabilities of the value falling in any size ranges between the high and low values.

The decision-maker can then inspect the subjective probabilities and revise them if necessary. He may, after inspection, wish to change the high, low or most likely values and recalculate using the triangular formulas. Alternatively, he may just revise the distribution, making sure that it continues to add to 1.0.

Chapter 5

RISK - TAKING ATTITUDES

In previous chapters we have discussed how to assess risk using the framework of the payoff matrix and personal probabilities. After you have made this assessment of the risks involved with a particular decision choice, the next step is to evaluate your attitude about assuming these risks. The amount of risk involved in the decision depends on the sizes and probabilities of possible gains and losses. Each decision choice will involve different amounts of risk. Your attitude about these risks depends on your objectives and your financial position.

Farmers and their families, like all people, have goals and objectives about what they wish to get out of life. These objectives will naturally vary considerably among farmers. Although objectives can be expressed and measured in a variety of ways, it's likely that at least two of these objectives will relate to income and safety. Increased income is required for a higher standard of living, but the farmer must also be concerned about the safety or survival of the farm business. While the farm must make money to stay in business and provide an acceptable standard of living, the objective of increased income may be traded-off for reduced risk or increased security for the business.

In the process of management, the farmer specifies his objectives and establishes some order or priority regarding their achievement. It is a difficult process to list all of the things we would like to achieve. It is even more difficult to establish priorities for each of these objectives, because they often conflict with one another. For example, the farmer might like to increase his net income, but to do so involves an increase in risk, jeopardizing the survival of the farm business. The particular combination of risk and income he chooses will depend on his relative priorities between these two objectives. It is these varying objectives and priorities regarding income and risk that explain why farmers, when faced with the same situation, will react differently.

In addition to the sizes and probabilities of gains and losses and the objectives of the decision maker, a third consideration influences how an individual manager will react to risk. This is the farmer's financial position which determines his risk-taking ability, or the vulnerability of the business to risk. The financial position influences the manager's objectives regarding risk taking, and the financial position relative to the potential gains and losses for a particular decision determines how significant those consequences might be. The farmer's financial position is measured through solvency ratios and cash flow requirements.

Just as we classify people as being optimistic or pessimistic, conservative or liberal, we can classify them according to their attitudes as risk averters (avoiders) and risk takers. It's important to recognize that classifying decision makers according to their attitudes about risk taking, does not reflect on their level of management or managerial ability. There are successful farm managers who tend to be risk takers and there are successful farm managers who usually like to avoid risk. They each have their own management style reflecting that there is more than one way to successfully manage a farm business.

HOW RISK ATTITUDES ARE INFLUENCED

The following hypothetical situations will illustrate how (1) the possible gains or losses, (2) objectives, and (3) financial position affect our attitude about the risk associated with a particular decision. Put yourself into each of the following four hypothetical situations and decide for each whether you would accept the bet.

1. You are offered a wager in which you will gain $20 if a fair coin falls heads, or lose $10 if it falls tails.
2. You have accumulated a fortune with a cash value of $5 million. You are now offered the opportunity to triple this fortune (a gain of $10 million) if a coin falls heads, or lose the entire $5 million if it falls tails.
3. With sacrifice, you have accumulated $5,000 in a savings account which you plan to use for a vacation this month in Florida. The vacation will require the entire $5,000. You are offered a bet that will yield a profit of $5,000 (you would have twice as much to spend on your vacation) if the coin falls heads, or a loss of $5,000 (which would mean postponing your long-planned vacation) if it falls tails.
4. You are desperate to take a camping fishing trip to Alaska. You have $5,000 available in cash, but the total expenses will amount to $10,000. You are offered a chance for a profit of $5,000 (enough to finance the trip) if the coin falls heads, or a loss of the $5,000 you now have if it falls tails.

Before reading on, write down your responses for each of these four situations. Would you accept the bets? Yes or no?

The authors would accept the bets in situations 1 and 4, but would say "no" in situations 2 and 3. Why the different responses in situations 1 and 2? The two situations are similar in that the possible gains are twice as large as the possible losses for both. What causes the difference in the acceptance of the bets? The explanation is found in the sizes of these potential gains and losses compared to the financial resources you have available in each of these hypothetical situations. In the first, a potential loss of $10 would not be a serious consequence for most readers. You would probably be willing to accept the consequences of this loss compared to the potential gain of $20. In situation 2, however, your entire fortune is at stake. The gain of $10 million (tripling the fortune) probably would not increase your satisfaction enough to offset the considerable decrease in satisfaction resulting from the possible loss of the entire fortune.

In situations 3 and 4 the dollar amounts of the gains and losses are exactly the same. The differences between these two situations lie in your objectives and their accomplishment. In situation 3, participation in the bet would jeopardize the accomplishment of an objective, while in situation 4, the objective could be accomplished only through the acceptance of the bet.

EVALUATING THE FINANCIAL ABILITY TO TAKE RISK

Before delving more deeply into the attitudes about risk taking, let's take a look first at how we can measure and evaluate the farmer's financial position which influences these attitudes. We will do this by looking at three example farm situations. On the surface these three farms would look exactly the same, producing the same crops on the same amount of land with the same machinery and equipment. The differences lie in how the farming resources are controlled and financed. In these examples we will look first at the net worth and solvency of each operation, then we will examine the cash flow requirements of each.

The financial position of the firm depends on its net worth and the relationship between this net worth and the total debt outstanding. This is commonly measured with the "debt to net worth ratio" which measures the adequacy of equity relative to debt. The lower this ratio the safer is the business's financial position and the more able it is to assume risk.

Cash flow represents the movement of dollars in and out of the business. Cash flow requirements are the obligations for cash costs, taxes, and loan repayment that must be met each year. The higher these requirements, the less able the business is to assume risk.

Following are three examples to illustrate how risk taking ability can vary among farms.

Oscar Olson

The first example is the case of Oscar Olson who has full ownership of his farm. Oscar owns a 2000-acre grain farm. He also has full ownership of a line of machinery for farming this acreage. The only borrowed capital is for operating expenses.

Oscar's assets consist of cash in a checking account, a grain inventory valued at $100,000, machinery, and land (Table 5-1). Oscar's only liability is an operating note for $45,000. Oscar's net worth is $665,000 with a "debt to net worth ratio" of .07.

The gross income Oscar receives for his crop must cover his cash requirements. His operating costs, including seed, fertilizer, chemicals, insurance, interest, fuel, repairs, land taxes, etc., amount to $45,000. In addition, sufficient cash must be available to replace machinery and cover annual living expenses including income taxes. This requirement amounts to $39,000. Total cash requirements then are $84,000. With cash receipts less than $84,000, Oscar would have to draw on his net worth to maintain the business.

To demonstrate Oscar's ability to handle a substantial amount of risk, suppose that there is a drop in grain prices affecting the value of his grain in inventory. Suppose that the price drops 20 percent reducing the value of grain on hand by $20,000. The total value of business assets would be reduced to $690,000 and net worth would decrease to $645,000, a decrease of 3 percent.

Roy Riggins

The second example is the case of Roy Riggins who rents his farm consisting of 2000 acres of grain land. He has a machinery loan and borrows capital for operating expenses.

Roy's assets are similar to Oscar's; however because Roy is a renter, the land is not included in his assets (Table 5-1). Roy has a short term operating note for production expenses similar to Oscar, but it is slightly smaller because he has no real estate taxes to pay. However, he has land rent due of $40,000. He also has a machinery loan with a remaining balance of $41,800. Roy's net worth amounts to $109,200, substantially less than Oscar's, and the debt to net worth ratio is 1.11. In other words, his debt exceeds his net worth.

Table 5-1. Comparisons of Financial Ability to Take Risk Based on Net Worth, Debt to Net Worth Ratio, and Annual Cash Flow Requirements.

	Oscar Olson (owner)	Roy Riggins (renter)	Bob Boyer (buyer)
Assets			
Cash	$ 10,000	$ 10,000	$ 10,000
Grain on hand	100,000	100,000	100,000
Machinery	120,000	120,000	120,000
Land	480,000	0	480,000
Total	$710,000	$230,000	$710,000
Liabilities			
Operating note	$ 45,000	$ 39,000	$ 45,000
Machinery loan		41,800	41,800
Land rent		40,000	
Land loan			334,700
Total	$ 45,000	$120,800	$421,500
Net Worth	$665,000	$109,200	$288,500
Debt to Net Worth Ratio	.07	1.11	1.46
Cash Requirements			
Operating costs	$ 45,000	$ 39,000	$ 45,000
Machinery payment		13,200	13,200
Land		40,000	36,600
Capital & living	39,000	21,600	24,800
Total	$ 84,000	$113,800	$119,600

The gross receipts Roy receives for his grain must cover the operating costs plus an additional $13,200 for principal and interest on the machinery loan. The land rental payment adds another $40,000 and machinery replacement requirements and family living expenses add another $21,600 (note that capital and living expenses are lower because of the different income tax situation) for a total of $113,800.

A 20 percent drop in grain prices would reduce Roy's assets by $20,000 to $210,000 and net worth would be reduced to $89,200 or a decrease of 18 percent. The debt to net worth ratio would climb to 1.35.

Roy, the renter, cannot financially accept the risk that Oscar, the owner, can.

Bob Boyer

The third example is of Bob Boyer. Bob has recently purchased his 2000 acre grain farm. He borrows his operating capital, has partial equity in his machinery line, and has a mortgage on the land.

Similar to Oscar, Bob's financial statement consists of cash, grain inventory, machinery, land, and an operating note (Table 5-1). However, he has additional liabilities consisting of a machinery loan with a current balance of $41,800 and a land loan of $334,700. His total liabilities amount to $421,500 giving a net worth of $288,500. The debt to net worth ratio is 1.46.

The gross income Bob receives for his grain must cover operating costs and and the machinery loan payment of $13,200. Bob must also cover the land payment equal to $36,600 dollars. To cover capital replacement and family living expenses requires another $24,800, giving a total annual cash requirement of $119,600 for Bob's operation.

The 20 percent price decrease for grain and inventory indicates the impact of risk on Bob's financial position. Net worth would be reduced by 7 percent and the debt to net worth ratio would increase to 1.57. Bob cannot financially accept as much risk as Oscar.

Comparisons

Compared to Oscar, both Roy and Bob are less able to assume risk based on the cash requirements and financial position of their businesses.

	Annual Cash Required	Debt to Net Worth Ratio	$20,000 as % of Net Worth
Oscar	$ 84,000	.07	3%
Roy	113,800	1.11	18%
Bob	119,600	1.46	7%

Roy, the renter, compared to Bob, the buyer, requires less cash annually, however Bob does have a larger net worth base on which to fall back.

PROFILES OF RISK TAKING ATTITUDES

As described in the introduction of this chapter, managers can be classified according to their attitudes regarding risk. These attitudes regarding a particular risky decision will depend on the potential gains and losses associated with that decision and the manager's financial position and objectives.

At one extreme are the "risk averters." These are the more conservative types who have a preference for less risky investments. Risk averters are willing to sacrifice the small chance of higher income for reduced risk. At the other extreme are the "risk takers". These are the plungers, the more adventurous types with preferences for the more risky investments. Risk takers are willing to accept more risk in return for the small chance of a higher income. The risk neutral decision makers are between these two types. They will choose the decision promising the highest expected return over time, regardless of the sizes of the potential gains and losses.

Risk averters will tend to produce crops with more stable yields and prices and forward contract the sale of their produce. Risk takers, on the other hand, will be involved in enterprises with more variable income and tend to speculate in the marketing of their products.

The manager's attitudes regarding risk depend on personal feelings and temperament. To quote one farmer describing a neighboring cattle feeder, "his experience as a paratrooper in the army was good training for feeding cattle. Both take lots of guts." As you manage, you carefully consider your attitudes regarding risk taking and organize and operate your business to achieve an acceptable level of safety consistent with these attitudes. If you cannot sleep at night for worrying about the future of your farm business, the risk you are assuming is too great. You should explore ways to control these risks. In some cases this may involve compromising income and other objectives in order to achieve an acceptable level of risk. You should assess your aptitude for managing under the pressures of risk. Some farmers are mentally capable of handling more risk than others and this is an essential consideration in developing a management plan for the farm business.

If the manager is to be happy with his decisions, he needs to select them so as to be consistent with his attitudes regarding risk. To help you better understand your attitudes about risk taking, we will provide here an example and procedure for testing your risk taking preferences. In so doing, we will attempt to develop an understanding of the thought processes the manager uses in choosing among risky decision alternatives.

Before going further, however, we need to review the concept of expected value. The expected value is a mathematical calculation indicating the weighted average for possible payoffs. It is merely the sum of the possible payoffs with each weighted by its probability. For example, a decision alternative which has a possible gain of $500 with the probability of .4 versus a possible loss of $200 with a probability of .6, has an expected value of $80 ($500 x .4) - ($200 x .6). This indicates that if such a trade were made many times, it would sometimes result in a gain of $500 and sometimes in a loss of $200, but in the long run, the <u>average</u> gain would be $80 per decision.

The following should be read with pencil in hand. You should make notes or calculations to be sure that the examples are clear to you.

Assume that you are confronted with the following opportunity. You have a chance at a payoff of either $18 or -$10 and the probability is .5 for each of those cases. That is, based on the flip of a coin, you have an opportunity to receive $18 or pay $10. We would like to know what you would pay for this business opportunity. Remember that you are to receive $18 or pay $10, and you have a fifty percent chance at each. If you pay $5 for the opportunity your possible gain is $13, and your possible loss is $15. On the other hand, if you pay $2, your possible gain is $16, and your possible loss is $12. Please write the maximum amount you would pay for this gamble. ____________ Based on your response, you can be classified as a risk averter, risk taker, or risk neutral with regards to your attitude about the risk in this business opportunity.

The expected value of this game or decision opportunity is $4 (.5 x $18 + .5 x -$10 = $4). If you are unwilling to pay the expected value for the business opportunity, you are a risk averter. If you pay the expected value, you are a risk neutral, and if you paid more than the expected value, you are a risk taker.

If you were a risk taker, you valued the potential gain more than you feared the potential loss. The "risk premium" measures the difference between the expected value of the opportunity and the amount you are willing to pay for that opportunity. If you are willing to pay $5 for the gamble, the risk premium that you would pay is the expected value of $4 minus $5, or $-1. If you are only willing to pay $2 for the opportunity of an expected value of $4, then the risk premium that you would require to take the gamble is $2 ($4 minus $2). Thus a risk premium is negative for a risk taker, positive for a risk averter, and zero for the risk neutral.

It is not unexpected that a decision-maker, who is a risk-taker for one decision, will be a risk-averter for another. One explanation for this shift in risk attitude is the different sizes of gains and losses associated with different decisions. For example, let's assume that you are considering renting land. Your budgeting indicates a chance of gaining wealth of $18,000 over the next year. However, if certain unpredictable events occur there is also a chance of losing $10,000 of wealth now held. The land rental opportunity offers a .5 chance of gaining $18,000 and a .5 chance of losing $10,000. What would you pay to rent this land? Or, if you had this deal, what would you take to get rid of it? Either question will work. Write in the following blank what you would pay for the business deal. ____________ Did you react as a risk taker or a risk averter to this high stakes gamble? The expected value of this opportunity to rent land is $4,000. If you were willing to pay more than $4,000, you are a risk-taker, if not you are a risk averter.

In summary, the purpose of this short exercise was to illustrate that farmers make decisions in a risky environment which differ from those of their neighbors. Decisions may differ because the information is not the same. They may also differ because of attitudes about taking a chance. Attitudes toward taking risk affect decisions of individuals. Failure to rationally analyze attitudes toward risk may affect the financial and emotional well being of the decision maker.

Another important point made by this exercise is that individuals' attitudes about risk taking change among decisions and over time. In the exercise we looked at two different decisions, one involving an $18 gain and a $10 loss, the other involving a $18,000 gain and a $10,000 loss. You may have been willing to pay more than the expected value for the first gamble, but willing to pay only something less than the expected value for the second. Therefore, you were a risk taker in the first case and a risk averter in the second. The same is true in farming. Managers may react as risk takers to some decisions and then be risk averse for another. This can be explained by differences in the magnitudes of the gains and losses. Measuring how risk attitudes change with the levels of the gains and losses is the topic of the next section.

Risk attitudes will also change over time. This is to be expected because people's objectives change over time and also the financial position of the business changes as additional capital is acquired and/or debt incurred. Thus, as is characteristic of much human behavior, it becomes difficult to predict how individuals will react to risky situations. Their attitudes regarding risky decisions will depend on their objectives, their financial position, and the sizes of the possible gains and losses associated with that particular decision.

MEASURING CHANGES IN RISK ATTITUDES

Using the concept of the "risk premium" introduced in the previous section, it is possible to measure how a person's risk attitude changes depending on the level of gain and loss. To obtain a perspective of a manager's approach to risk in the making of day-to-day farm decisions, it is necessary to consider his reaction to various sizes of gains and losses. It is not reasonable to consider the manager's risk attitude for gambles around $100 and then apply these results to decisions involving gains or losses of, say, $10,000.

Before going through a procedure to estimate your risk attitude at various levels of gains and losses, let's again look at the expected value (EV) concept. Suppose you can toss a coin for a win or loss of $10. The EV of this gamble is $0. If it were possible to win $1,000 or lose $1,000, each with a probability of 0.5, the EV is still $0. However, the implication of a possible loss of $1,000 is considerably different than a loss of $10. On the other hand, the $1,000 win is a much more enticing prospect than is $10.

Now we'll consider a procedure that could be used to help you think about how your attitudes about risk-taking vary for different decisions. This procedure involves a series of hypothetical games. For ease of understanding the probabilities of winning or losing are equal, that is, 0.5 each, and the money to be won equals what can be lost for each game. The object of this series of games is to get you to think about whether you are a risk averter or risk taker, and to what degree, for games involving alternative levels of gains and losses. Your job is to answer the questions as honestly as possible, assuming that you are actually participating in the gambles. The amounts of money used in the game are intended to be representative of the amounts of money that might be involved in some of the decisions you must make in your own business in uncertain situations.

You will be asked to decide the maximum amount you would pay to participate in each game, or the amount you would have to be paid to induce you to participate. Let's start with a small example. Suppose you have the chance to win or lose a $20 bill based on a coin toss. Would you pay something to participate in this gamble? If you would, you are a risk taker, at least for this gamble. Would you participate if you did not have to pay and no one paid you? The EV is zero. If you would participate on this basis, you are risk neutral for this gamble. Would you participate if you were paid something? How much would you have to be paid? Suppose you say $4? You would be a risk averter and require a $4 risk premium for this game.

Now consider a higher stakes game. You have equal chances of winning $100 or losing $100. The EV is again $0. How much would you pay to play this game? Or, would you need to be paid to play the game? Suppose you say $30. You have a $30 risk premium for this gamble. Your risk premium for this game is 30 percent of the possible amount to win or lose, which is higher, in percentage terms, than your $4 risk premium for the $20 game which is 25 percent.

If you understand the two games we just played, you are ready to proceed with our series of games. If not, please read this section again before proceeding.

In each of the following games, you must decide the <u>most</u> you would pay to participate in the game or the <u>least</u> someone would need to pay you to induce you to participate. Take your time and think carefully about each game, answer the question, and then move on to the next question.

The seven games are all even money bets, that is, the amount you would win or lose is the same. The EV of each of these bets is zero, in other words, if the game could be played many times the net winnings or losses of the player would approach zero if he neither paid or was paid to participate. A risk neutral person would neither pay nor need to be paid to play any of these games. Each bet is larger than the previous bet. This set of games is designed so that you can ascertain whether your attitude about risk taking changes as the size of the possible gain and loss is increased.

Your risk attitude will be related to your present wealth or net worth situation. For example, you might be able to stand a $1,000 loss with little difficulty. Your spouse might never know you lost it. Therefore, you might require a very small risk premium. A $2,500 loss might be much more disastrous. You might not be able to conceal this large a loss from your friend, to say nothing of your spouse. Therefore, you might require a much larger risk premium relative to the size of the possible win and loss. Similarly a loss of $5,000 might be increasingly disastrous. It is possible though, that a larger loss would be not much worse than a $5,000 loss. For example, a $5,000 loss might bankrupt you and a $10,000 loss wouldn't bankrupt you any worse. Therefore, your risk premium for a $100,000 gamble might not be any larger (even in absolute terms) than your risk premium for a $10,000 gamble.

Game number	Possible gain	Possible loss	Probability of winning	What is the game worth to me? I would PAY at most	I would REQUIRE at least
1	$ 100	$ 100	0.5	$______	$______
2	250	250	0.5	______	______
3	500	500	0.5	______	______
4	1,000	1,000	0.5	______	______
5	2,500	2,500	0.5	______	______
6	5,000	5,000	0.5	______	______
7	10,000	10,000	0.5	______	______

By plotting on graph paper the amount you would pay or require to participate in each game, you should be able to see your degree of risk aversion for various sizes of gambles. Where your plots fall on the horizontal center line you are risk neutral. Plots above the center line indicate risk aversion. Risk taking plots fall below the center line. Once you have plotted your risk premiums for the various gambles, join the dots with a line.

Now look at the line you have drawn. If the line is straight (or approximately so), your degree of risk aversion is a constant proportion over the range of $100 to $10,000 gambles. Your risk premium is the same percentage of the possible wins (or losses) over the entire range. However, if your line increases at an increasing rate (curves upward), you are more risk averse to larger gambles. If your line increases at a decreasing rate (curves downward), you are less risk averse to larger gambles.

Figure 5-1 shows the risk premium curves for two hypothetical decision makers. Manager A has increasing risk aversion in relation to the size of the possible win or loss. Manager B's curve reflects a mixed situation. For gambles below $1,500 he is a risk taker. He is risk neutral at $1,500, and becomes increasingly risk averse as the size of the gamble increases above $1,500.

Even without directly using this "risk premium" concept in making decisions, the nature of one's attitudes about accepting uncertain gains and losses can help in analyzing investments as well as guiding day to day management decisions. It is clear that a risk averter, if he knows himself, will make decisions differently than if he were a risk taker or risk neutral. These attitudes about risk taking are and should be considered in your decision-making process.

CONSIDERING RISK ATTITUDES IN A DECISION CHOICE

Up to this point we have discussed how your objectives, financial position, and the possible gains and losses of the decision will affect your attitude about taking the risk associated with a particular decision. Now we will put this all together and apply it to an example decision. We will take the example of a cattle rancher who has a choice among six different plans that he could implement for his operation. The question is "which of the six plans should he select?" Before he can select a plan he must establish his relative priorities regarding income and the safety or survival of the farm business. One way to establish these priorities is to first order these two objectives and then establish what are satisfactory levels of attainment. When this is done, the first objective must be met or satisfied before the second is considered, and so on until all the objectives are either maximized or satisfied.

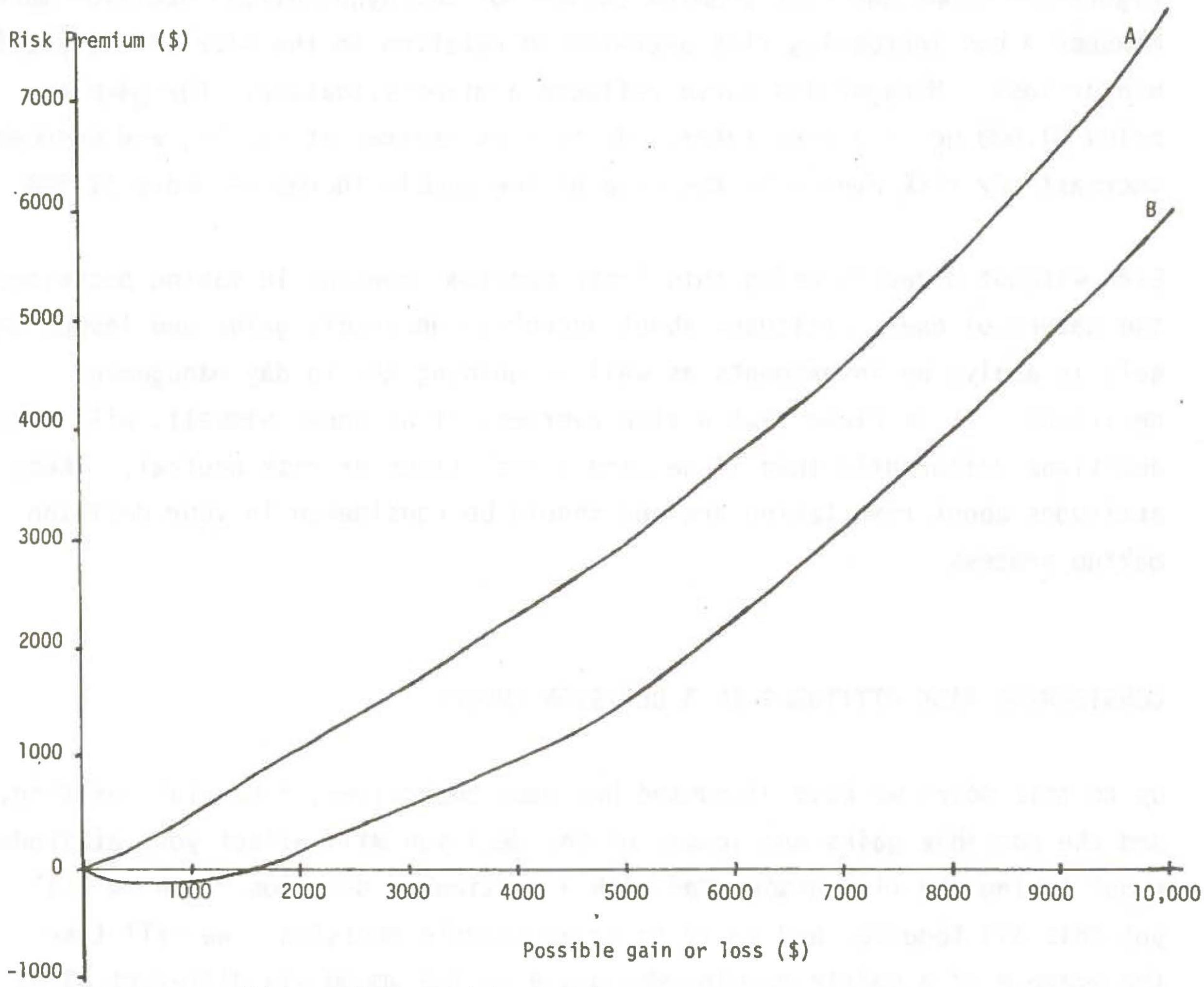


Figure 5-1. Risk Premium Curves for Two Decision Makers

For this example it is assumed that the first objective of the manager is to insure the survival of the ranch business. Survival depends on (1) what constitutes a "disaster" level of income and (2) what probability the rancher is willing to accept of having income less than this "disaster" level. The second objective, once this first objective is satisfied, is assumed to be the maximization of expected net income. (Note this is the safety-first rule discussed in Chapter 2.)

The rancher has analyzed his financial position and has found that he has a cash requirement of $30,000 per year. Thus, he would consider an annual income of less than this amount as a disaster because he would not be able to meet annual land payments and family living expenses. Let's assume then that the rancher requires that the plan he selects will provide at least $30,000 annual income 90 percent of the time.

The income and risk characteristics of the six ranch plans are indicated in Table 5-2. Using budgeting analysis and considering the probabilities associated with prices and production, the rancher has available to him the information regarding expected net income and the lower level of net income which the plan will exceed at least 90 percent of the time. Ranch Plans A through D satisfy the rancher's first priority which means he can expect Plans A through D to produce at least $30,000 net income 90 percent of the time. He also notes that Plan F produces the maximum net income.

Given his objectives regarding increased income versus survival, the example rancher will choose Plan D. This plan produces $65,000 net income versus the maximum-income plan's $76,000. Thus the rancher in this example is willing to give up $11,000 of average net income in return for the "safety" of a minimum income of $30,000 in 9 years out of 10.

Ranch Plan D differs considerably from Plan F. The resources of the ranch are allocated differently, and the sizes of the cow herds under the two plans differ. But the important point is that Plan D is consistent with the ranch manager's objectives, finances, and attitudes about the risk inherent in his ranching operation.

Table 5-2. Minimum Net Incomes (90-Percent Probability Level) and Expected Net Incomes for Six Example Ranch Plans.

Ranch plan	Minimum net income (90%)[a/] ($)	Meets minimum income objective	Expected net income ($)
A	36,000	Yes	41,000
B	37,000	Yes	46,000
C	34,000	Yes	58,000
D	30,000	Yes	65,000
E	27,000	No	68,000
F	4,000	No	76,000

[a/] Minimim level of income for respective plan which will be exceeded 90 percent of the time, i.e., there is a 10 percent probability that it will not be achieved.

SUMMARY REMARKS

This chapter has discussed how attitudes towards risk taking are formulated and how they influence decision making. The attitude about risk taking associated with a particular decision will depend on the possible gains and losses associated with that decision, the objectives of the manager, and the financial position of the farm business.

The financial position of the business determines its vulnerability to the risk and thus conditions the risk taking attitude that will be exhibited. The manager's financial ability to take risk can be evaluated in terms of the net worth and solvency of the business and its cash flow requirements. As indicated by the example, farms of the same size and composition can vary considerably in their ability to assume risk.

There are three classifications of managers in terms of their attitudes about risk taking. They can be risk averters, risk takers, or risk neutral.

Risk averters are more conservative and are willing to sacrifice the chance for higher income to achieve reduced risk. Risk takers are more adventurous, willing to accept more risk in return for the chance of higher income. Risk neutral decision makers find themselves between these two types, seeking to maximize expected income.

These attitudes about risk taking are transitory, however. A decision maker may be a risk taker for one decision and then seek to avoid risk with another. This is quite consistent when one considers that different decisions have different sizes of potential gains and losses associated with them and that financial resources and objectives change over time.

While it is difficult to directly incorporate one's attitudes about risk taking into the decision making process, the "risk premium" concept is useful in revealing these attitudes and understanding their implications. It is these attitudes that set you apart from other farm managers as a unique individual.

Appendix

UTILITY FUNCTIONS

Another approach for considering the decision maker's attitudes about risk-taking in the decision making is to elicit his utility function and determine his best decision by maximizing expected utility. Economists use the term utility as a measure of satisfaction. Maximizing utility can be thought of as maximizing satisfaction in risky situations.

For many individuals the marginal value of an extra dollar's worth of net income or wealth declines, at least after some level of net income. For example, $40,000 worth of net income may not be worth twice as much as $20,000 worth of net income. Presumably, $20,000 income gives this type of person most of what he wants out of life and $40,000 does not double his utility or satisfaction.

Assume that the utility scale is arbitrarily defined in units of utility or utils from 0 to 100 as shown in Figure A-1. Because it is generally believed that the marginal value of an extra dollar's worth of income or wealth to an individual declines, at least after some level of income, a general utility curve may be drawn as shown in Figure A-1. Figure A-1 is based on the data in Table A-1.

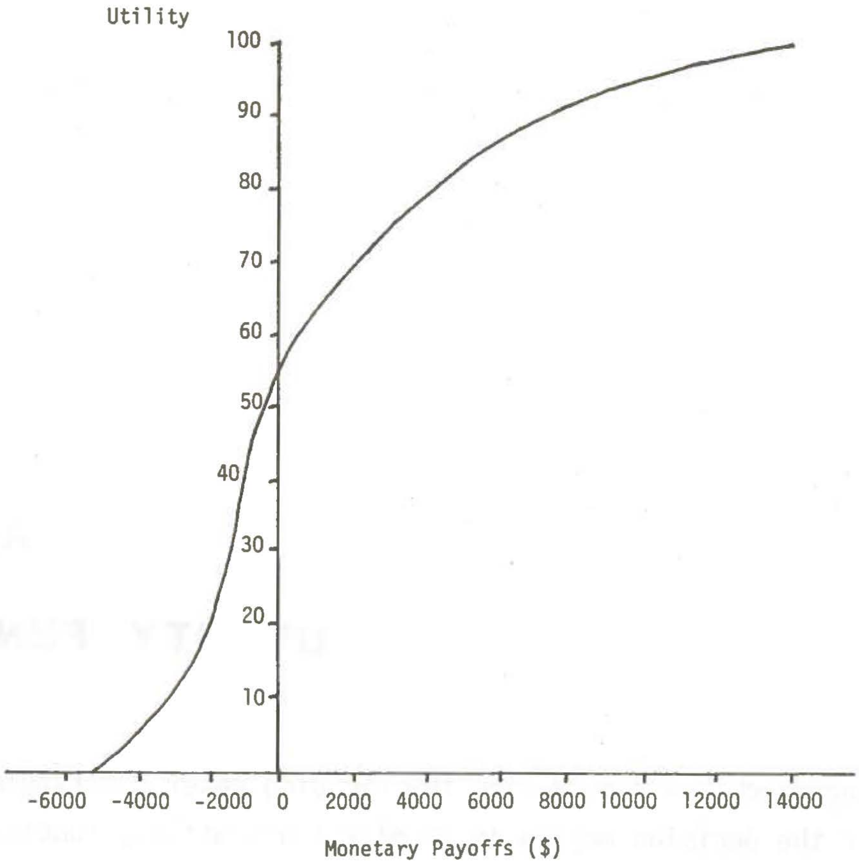


Figure A-1. An Example Utility Curve

Table A-1. Computations of Utilities for Gains and Losses in Wealth - An Example

Utilities of		Probabilities of		Computed Utility of the Alternative (Col. 5)	Cash Equivalent of the Trade in Dollars (Col. 6)
Best Outcome (Col. 1)	Worst Outcome (Col. 2)	Best Outcome (Col. 3)	Worst Outcome (Col. 4)		
100	0	1.0	0	100	14,000
100	0	.95	.05	95	10,000
100	0	.9	.1	90	6,500
100	0	.8	.2	80	4,000
100	0	.7	.3	70	2,000
100	0	.6	.4	60	250
100	0	.5	.5	50	- 250
100	0	.4	.6	40	- 500
100	0	.3	.7	30	-1,600
100	0	.2	.8	20	-2,000
100	0	.1	.9	10	-2,500
100	0	0	1.0	0	-5,000

Figure A-2 and Table A-2 show alternative utility functions for a risk averter (I), a risk neutral person (III), and a risk taker (II). In the case of the risk taker, the utility of gains is increasing. For the risk neutral person, we have the case of constant utility for money in which marginal utility of each additional dollar of gain is constant as is the marginal utility of dollar of loss. This decision maker can maximize expected monetary value without going through the procedure of maximizing utility.

The risk premium for a risk averter and the value of a gamble (negative risk premium) for a risk taker can be identified in the graph and table. The risk neutral person gets equal utility from a sure $600 and a chance at $600, e.g., utility of the gamble equals the utility of the expected monetary value (EMV) of the gamble as shown in Figure A-2. The risk averter gets more utility from a sure gain of $600 than a chance of $600 made up of an 0.8 probability of gaining $1,000 and 0.2 probability of losing $1,000 in Figure A-2. In fact, he would be equally happy with about -$170 as a chance at $600. His certainty equivalent is $170 and his risk premium is $770. In contrast, the risk taker would pay $900 - 600 = $300 for the privilege of the gamble. His utility of the gamble is greater than the utility of the EMV.

A person's utility function does not necessarily have the same general shape over all ranges of utility and income. The utility function could have a portion of increasing utility of income followed by a portion of decreasing utility for income or vice versa. It could also have a portion of constant marginal utility of income.

DERIVING A UTILITY FUNCTION

Table A-1 was obtained from a specific decision maker by a questioning process. A utility of 100 was specified for the best outcome ($14,000) and a utility of zero for the worst outcome (-$5,000). The next two columns specify probabilities of receiving the worst outcome and the best outcome.

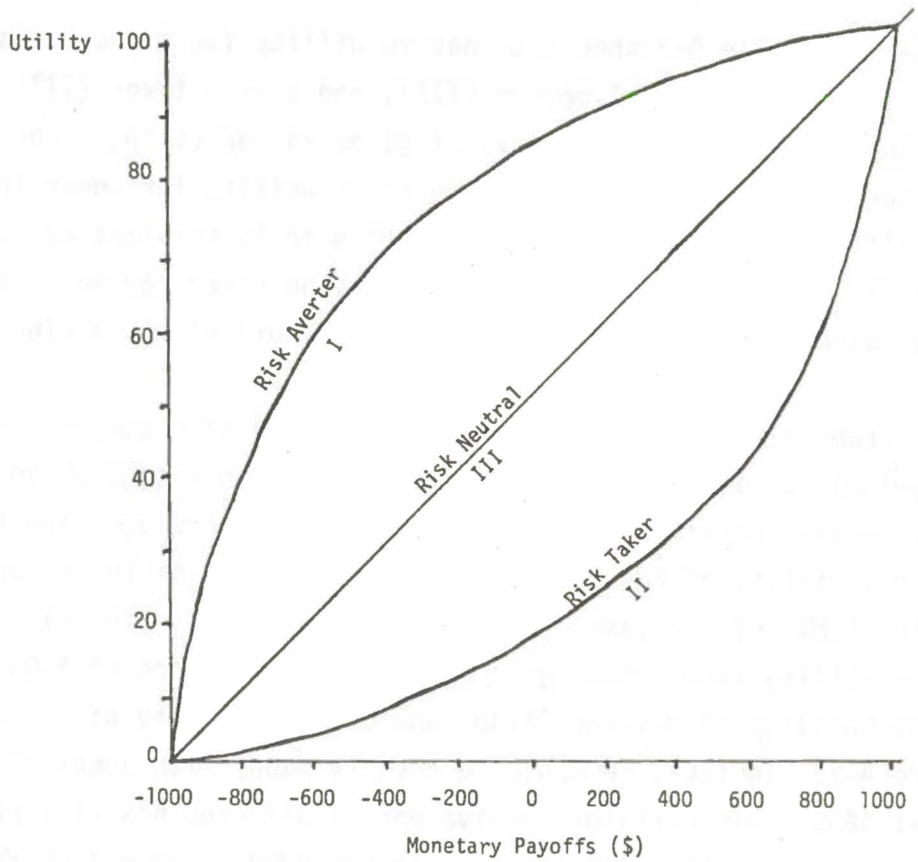


Figure A-2. A Comparison of Three Example Utility Functions

Table A-2. A Comparison of Three Example Utility Functions.

Hypothetical Gambles			Certainty Equivalent			
Probability of gaining $1,000	Probability of losing $1,000	Expected monetary value	I Risk Averter	II Risk Taker	III Risk Neutral	Utility
1.0	0.0	1,000	1,000	1,000	1,000	100
0.8	0.2	600	- 170	900	600	80
0.6	0.4	200	- 580	820	200	60
0.5	0.5	0	- 700	720	0	50
0.4	0.6	- 200	- 810	580	- 200	40
0.2	0.8	- 600	- 940	80	- 600	20
0.0	1.0	-1,000	-1,000	-1,000	-1,000	0

For example, the first alternative is a sure chance of $14,000 and no chance of the worst outcome. We assign the utility of that outcome as 100. On the next line we have the probability of .95 for the best outcome and .05 for the worst outcome. Using the expected utility idea, (.95 (100) + .05(0) = 95), 95 is the utility for that outcome. The probability pairs are varied all the way to a zero chance of the best outcome and probability of 1 for the worst outcome.

Hopefully, attitudes of the decision maker are captured in the final column. The first value simply says that he would be equally happy with a sure chance of a $14,000 gain and $14,000 in cash. The last value says that he would be equally happy (unhappy) with a sure chance of a $5,000 loss and a $5,000 cash loss, since these are equivalent.

The expected monetary value of the outcome for the second row is .95($14,000) + .05(-$5,000) or $13,050. The first question might be, if you had a chance of making an "expected" $13,050 in the situation described, what would you take for that opportunity? Would you take $13,050? Would you take less? Would you take more? Let's say that the answer that we get is that we would trade the risky prospect for a sure $10,000. We proceed to question the decision maker and, as a result, get the cash equivalent values shown in Table A-1.

At this point, we have a relationship between a numerical measure of utility, for which the scale is arbitrary, and a risky venture. The certainty or cash equivalent is a substitute for that risky venture. We can use the cash equivalent as a proxy and plot the certainty equivalent against the utilities, as shown in Figure A-1.

Obviously, one thing that we can do with Figure A-1 is read the utility forthcoming from different levels of gain or loss. These utility values can be used to substitute for the dollar values in a payoff matrix. Once the substitution has been achieved, the "maximize expected utility" approach can be employed as a means of choosing the optimum action.

Even without using the concept of maximizing expected utility in a decision theoretic problem, the nature of one's feelings about accepting gains and losses could help in guiding decision choices in business. A risk averter, if he knows himself, would decide differently than if he were a risk taker or risk neutral.

Table A-3 is for your use in deriving utility curves for yourself. Several things should be kept in mind as ground rules for your self-interview.

1. This is not a test. No one answer is more correct than another. An attempt is simply being made to measure attitudes about gains and losses and money at a point in time. If the test were given later at a different wealth position, age or attitude, there could be a significant change in the curve.
2. The dollar amounts gained or lost should be considered as real dollars with real purchasing power. If the dollars are lost you should imagine that real pain will result, and if the dollars are gained they will be available for immediate use in whatever way desired. Thus, your feelings should reflect your attitude about the gain and about the loss as though they are in fact real.
3. There is no time lag between the gains and the time you receive the gain or losses and the time you have to pay the loss.
4. You may want to use a paper and pencil. For example some may want to figure the expected monetary value of the gamble as an aid in thinking about the prospect. Consider each trade and level of risk capital separately. Problems of consistency will be considered at a later time.
5. The rule for setting the maximum loss and the maximum gain is to consider either a range of business transactions within your experience or a range of gains or losses which represents the prospective venture that you have in mind.

Following this procedure, the utility functions of an individual can be specified by answering questions about how he would react to a series of hypothetical gambles. The decision maker would be expected to make actual decisions in risky situations reflecting the same attitudes as he displays in the hypothetical gambles. The advantage of the utility function is that once it is specified it can be applied to a series of decision problems. A person's utility function may change over time as his wealth changes and as his experience with uncertain situations changes. His attitude toward risk may change and therefore his utility function will change.

Table A-3. Table for Computation of Utilities for Gains and Losses in Wealth.

Utilities of		Probabilities of			
Best Outcome (Col. 1)	Worst Outcome (Col. 2)	Best Outcome (Col. 3)	Worst Outcome (Col. 4)	Computed Utility of the Alternative (Col. 5)	Cash Equivalent of the Trade in Dollars (Col. 6)
100	0	1.0	0	100	________
100	0	.95	.05	95	________
100	0	.9	.1	90	________
100	0	.8	.2	80	________
100	0	.7	.3	70	________
100	0	.6	.4	60	________
100	0	.5	.5	50	________
100	0	.4	.6	40	________
100	0	.3	.7	30	________
100	0	.2	.8	20	________
100	0	.1	.9	10	________
100	0	0	1.0	0	________

AN EXAMPLE OF MAXIMIZING EXPECTED UTILITY

Now we will illustrate how a utility function, assuming it is known, could be used to help make a decision in an uncertain situation. The decision to fertilize wheat lightly, moderately, or heavily for uncertain low, average or high rainfall (with probabilities of 0.2, 0.3, and 0.5) will be used as the example. The EMV's were:

A_1, Fertilize Lightly	$10,100
A_2, Fertilize Moderately	12,200
A_3, Fertilize Heavily	12,700

The risk neutral decision maker would fertilize heavily. Using the risk averter's utility function from Figure A-3, we obtain a different decision. Reading utilities for each payoff from the graph, we can construct a utility table for this situation.

		Actions			Actions		
		A_1	A_2	A_3	A_1	A_2	A_3
Probabilities	Events		Payoffs			Utilities	
0.2	E_1	8,000	5,500	2,000	39.5	32.0	17.5
0.3	E_2	10,000	12,000	11,000	45.0	49.0	47.0
0.5	E_3	11,000	15,000	18,000	47.0	55.0	60.5
			Expected Utility		44.9	48.6	47.85

Expected utilities, calculated by multiplying the payoffs by the probabilities of the states of nature, are 44.9, 48.6, and 47.85. The expected utility of A_2, Fertilize Moderately, is slightly higher than the expected utility of A_3, Fertilize Heavily. The decision maker with this utility function should fertilize moderately because his expected utility is highest for this action.

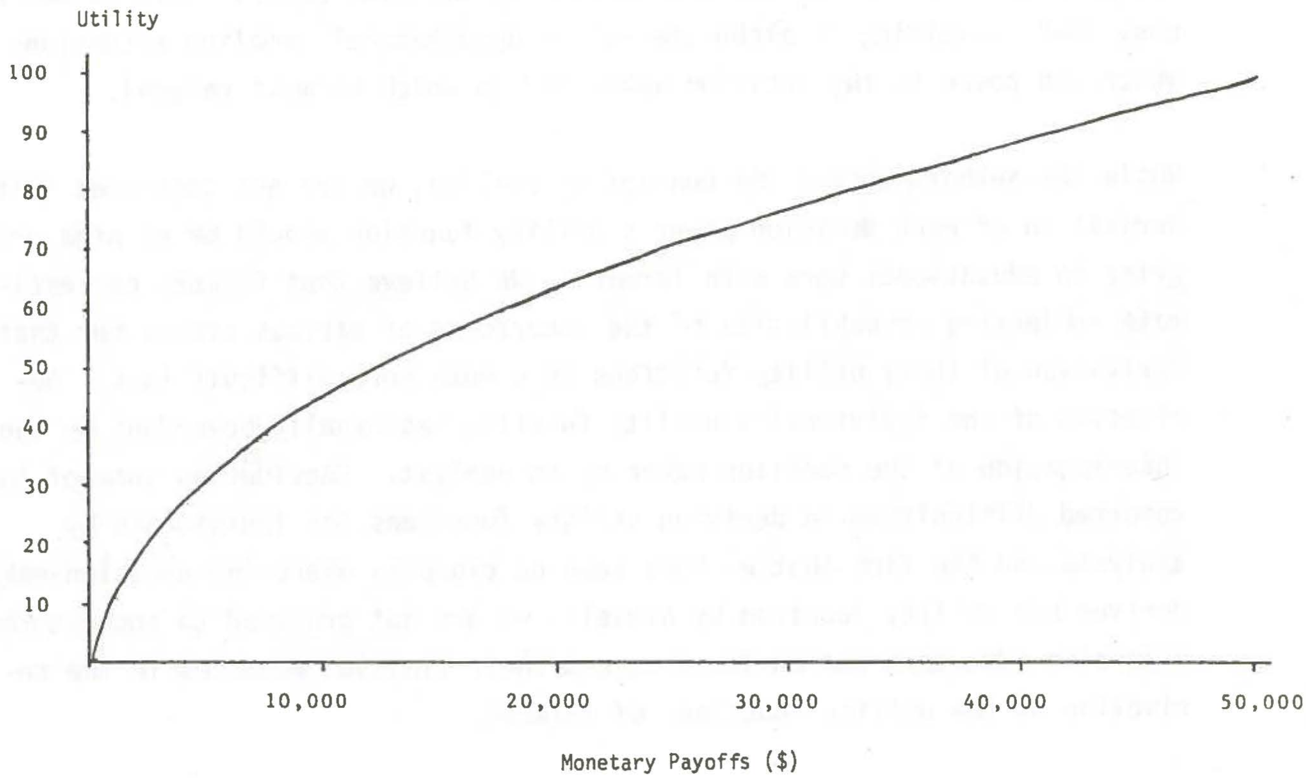


Figure A-3. Risk Averter Utility Function

CONCLUSIONS

The most general and formal decision rule is to maximize expected utility. This uses the subjective probability information, together with a functional relationship that describes the decision maker's attitude about risk, that is, whether he is a risk averter, risk neutral, or risk taker, or some combination thereof. The disadvantage of this approach is that this utility function must be derived for the individual decision maker. This is not an easy task, involving an elaborate set of hypothetical gambling situations which are posed to the decision maker and to which he must respond.

While the authors accept the concept of utility, we are not convinced that derivation of each decision maker's utility function should be of high priority in educational work with farmers. We believe that farmers can estimate subjective probabilities of the occurrence of various events but that derivation of their utility functions is a much more difficult task. Derivation of the individual's utility function has usually been done by the interrogation of the decision maker by an analyst. Considering some of the reported difficulties in deriving utility functions for individuals by analysts and the fact that we have seen no examples where the decision maker derives his utility function by himself, we are not prepared to suggest that extension educators and advisors expend their limited resources in the derivation of the utility functions of farmers.

As an alternative to the utility function approach, the authors have presented a more loosely structured approach based on the safety-first criterion. This is consistent with the concept of the decision maker as having multiple objectives some, or all, of which he seeks to satisfy rather than maximize. This approach also appears to be consistent with the way in which many decision makers view their risky decision choices. When the objectives of the decision maker are not made explicit, a trial and error process might be employed to allow the decision maker to feel his way towards his "best" action using the payoff and probability information.

Chapter 6

CONCLUDING NOTES

Sound management forms the basis of any successful farm operation. The application of the management techniques outlined in the preceding chapters will help you to weather those periods of adversity characteristic of most agricultural businesses. Possibilities of lower prices, production failures, or higher costs, with consequent slimmer profit margins, along with the ever present threat of casualty losses all require the most efficient management practices in order for the business to survive and provide an adequate return on investment. These techniques will no doubt be an important factor influencing the success of future farming operations.

Effective management requires planning which in its simplest terms means deciding what you are going to do today, tomorrow, and next year. Good planning involves formulating alternative courses of action, assessing the risk involved in these actions, and then choosing the best from among them. Management also involves carrying out your plans, or changing them as it becomes desirable or necessary.

Before making your plans, you will probably have given considerable thought to the goals you'd like to attain. Although goal-setting is frequently an unconscious process, you'll find it helpful to write down your goals.

Ask yourself, "Where do I want to be next year, five years from now, or at retirement?" You may find that you will have several goals such as increased income, growth, survival of the business, and preservation of an estate. You will have to decide priorities among these goals. For example, you will want to consider your priorities for increased income versus the long-run survival of the farm business.

Once you have set your goals and formulated some alternative actions, you'll want to start thinking in terms of budgeting. A management technique for guiding this budgeting process is the payoff matrix. The payoff matrix provides a convenient framework for summarizing the components of the decision problem, the alternative actions and the events (those uncertain occurrences beyond your control) which will determine the payoffs of the actions. The payoff matrix helps you consider the various sources of risk in your planning and indicates the range of possible results that you might expect for each action. It will allow you to evaluate your plans to insure that they are consistent with your goals.

The second management technique that will help you in summarizing what you believe about the future is the estimation of personal probabilities. These probabilities are numbers that measure the likelihood or chance that particular events will occur. Carefully estimated and based on all the information you can accumulate, they can be combined with your payoff matrix to evaluate the chances of both the favorable and unfavorable outcomes. Thus the payoffs combined with the probability information allow you to assess both the expected income and risk associated with your alternative plans.

The third aspect of management important in the planning of a risky enterprise such as agriculture, is the consideration of your attitudes about taking risk. Managers vary in their attitudes about risk taking. Some are conservative and would like to avoid risk while others are adventurous and are willing to take more risk. These attitudes are affected by your financial ability to take risk in terms of your net worth, solvency, and cash flow needs. Thus, you bring together your goals regarding income and business survival and assess your ability to assume risk in choosing the best course of action using the payoffs you budgeted and the probabilities you estimated.

This approach to dealing with the risk in farm decisions does not simplify or remove the agony involved in making these difficult decisions. However, it allows you to evaluate the choices that you face making use of all the information that you have available. The world will continue to be a risky one for the farm manager. The guidelines presented here offer opportunities for helping the manager deal with this risk.